BBC

SAVAGE OR BRILLIANT STRATEGIST?

Was Genghis Khan more than just a mindless psychopath? *p40*

ASIA EDITION

Knowledge

Vol. 7 Issue 11

SCIENCE • HISTORY • NATURE • FOR THE CURIOUS MIND

INCORPORATING BBC SCIENCE WORLD

THE HUNT

A matter of life and death *p28*

PPS 1745/01/2013 (022915)
(P) 055/11/2014 ISSN 1793-9836

9 771793 983016 11

SGD 7.50 | PHP 300
THB 240 | NT 200 | RM 16

Regent Publications

CATCH THE HUNT ON BBC EARTH THIS NOVEMBER

INTRICACIES OF THE MICROSCOPIC WORLD *p52*

UNDERSTANDING QUANTUM PHYSICS *p46*

STATUS UPDATES VIA NEUROTELEPATHY *p69*

tvhighlights

NATURE'S WEIRDEST EVENTS SR 3

Premieres 10th November. Tuesdays at 8.50pm (JKT/BKK), 9.50pm (SIN/HK/MAL/TWN)
This series unravels the facts behind a host of extraordinary natural events. From fish walking out of the water in Florida, killer sharks on an Australian golf course to a snake with two heads – this is the show that proves that, in nature, fact is often a lot stranger than fiction!

TRUST ME, I'M A DOCTOR SR 2

Premieres 13th November. Fridays at 9.40pm (JKT/BKK), 10.40pm (SIN/HK/MAL/TWN)

What is the truth about super foods and does caffeine really make you more alert? Michael Mosley and his team of doctors experiment on their own bodies to provide answers to the medical questions we face everyday.

TIGERS ABOUT THE HOUSE- WHAT HAPPENED NEXT

Premieres 15th November. Sundays at 4.00pm (JKT/BKK), 5.00pm (SIN/HK/MAL/TWN)

This series follows the Clark family as they travel deep into wild tiger territory. We also catch up with Spot and Stripe back in Australia to find out what the future holds for these cubs as they approach their first birthday.

EARTH'S NATURAL WONDERS

Premieres 29th November. Sundays at 4.00pm (JKT/BKK), 5.00pm (SIN/HK/MAL/TWN)

Combining the very best science and natural history filmmaking, this landmark series features some of the most amazing places on our planet, celebrating Earth's greatest natural wonders and revealing the dramatic and extraordinary lives of the people and creatures that inhabit them.

BBC earth

www.bbcasia.com

BBC Earth is available in Hong Kong, Indonesia, Malaysia, Mongolia, Singapore, South Korea, Taiwan, Thailand and Vietnam.
Please call your cable operator for more details or check out our website.

/BBCEarth
@BBCEarthAsia

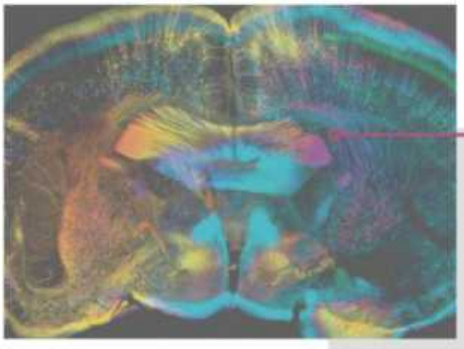
On the cover

Vol. 7 Issue 11

HISTORY

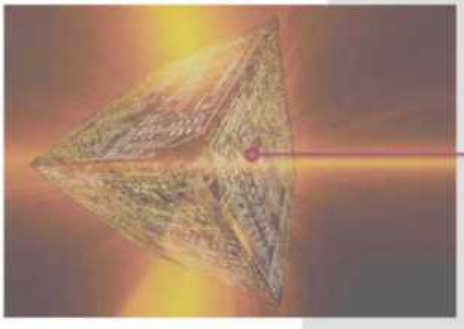
40 The Brutal Brilliance Of Genghis Khan

NATURE



52 Uncovering Nature's Hidden Beauty

SCIENCE



46 Quantum Physics In 10 Minutes

SCIENCE

69 Facebook Wants To Read Your Mind

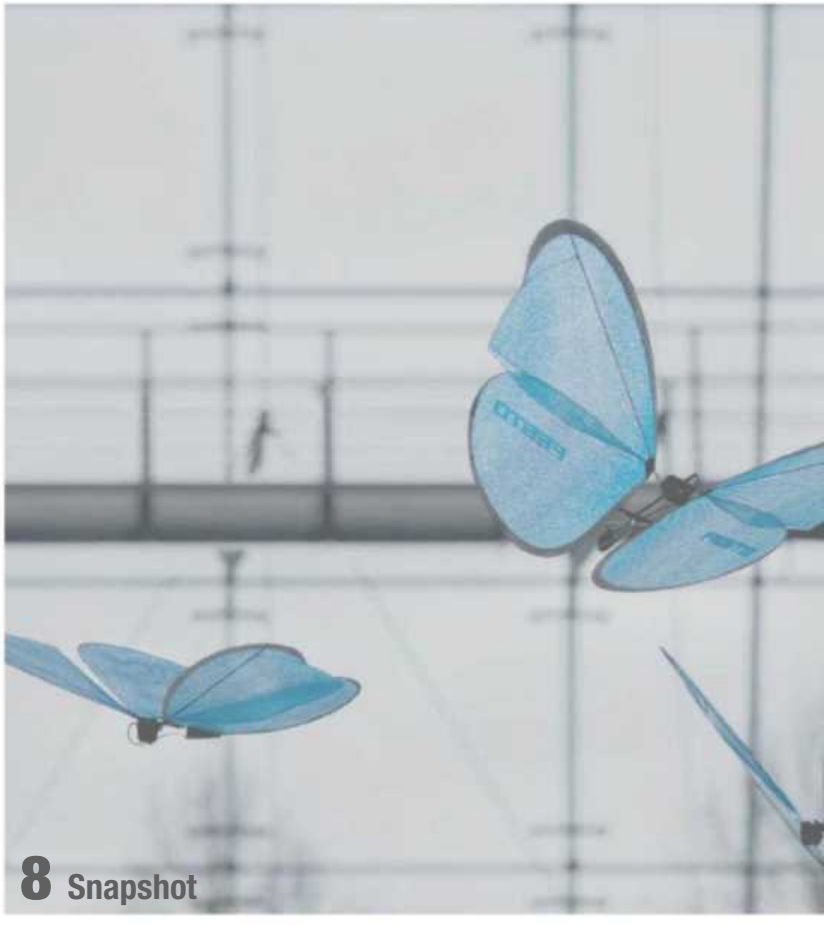
28 The Hunt

Contents

Vol. 7 Issue 11

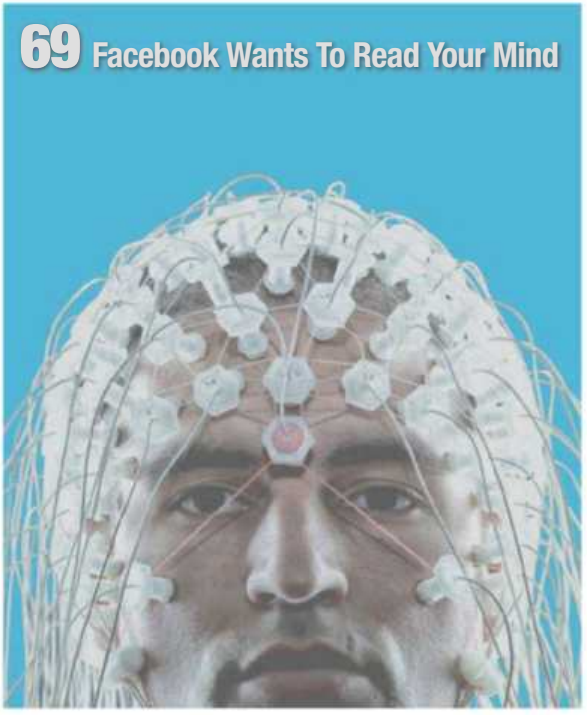
FEATURES

28 The Hunt



8 Snapshot

60 Nature's Weirdest Events



69 Facebook Wants To Read Your Mind

Welcome

✉ **Send us your letters**
editorial-bbcknowledge@regentmedia.sg

THE HUNT ISN'T ONLY ABOUT THE KILL

This issue our cover story truly epitomises the saying, "The Thrill Of The Hunt!"

It is also the main reason why many fishermen indulge in sport fishing, because they aren't necessarily hungry or need the fish but it is the whole process of preparation that includes getting the right boat that is equipped with the latest state-of-the-art fish finder, the right bait for the particular fish they are targeting as well as having the right lines, rods and reels. Once the fish is caught (and released), the whole euphoria of the hunt disappears and the whole process begins once again.

In the wild, the animals do not have the luxury of hunting for mere sport. It is a matter of life and death, for both predator and prey. As much as the world of wildlife movies and films would like it to be so, the outcome of a hunt is seldom set in stone where the seemingly weaker or physically disadvantaged animals fighting a losing battle. In fact most predators fail during their hunts, as much as 90% of the time!

Which is what this new series to be aired on BBC Earth is all about, taking us on an epic journey into the dramatic world of predation where the outcome of a hunt is never certain, much like life itself.

Ben Poon
ben@regentmedia.sg

"LIKE" US ON FACEBOOK! **www.facebook.com/knowledgemagazine**

✉ We welcome your letters, while reserving the right to edit them for length and clarity. By sending us your letter you permit us to publish it in the magazine and/or on our website. We regret that we cannot always reply personally to letters.

Experts in this issue…

Michael Banks

Michael is news editor of Physics World. On p52 he reveals Robert Hooke's key discoveries and takes us on a journey through the history of microscopy.

Rita Carter

Rita is an experienced writer, lecturer and broadcaster who specialises in the human brain. On p69 she takes a look at the machines that can read our minds.

Adam Hart

Adam is a BBC presenter, lecturer and bug-botherer. On p76 he tells us why we should be kinder to the wasps this summer – even if they do invade our picnics and barbecues.

✉ SEND US YOUR LETTERS

Has something you've read in BBC Knowledge Magazine intrigued or excited you? Write in and share it with us. We'd love to hear from you and we'll publish a selection of your comments in forthcoming issues.

Email us at:

editorial-bbcknowledge@regentmedia.sg

We welcome your letters, while reserving the right to edit them for length and clarity. By sending us your letter you permit us to publish it in the magazine and/or on our website. We regret that we cannot always reply personally to letters.

BULK SUBSCRIPTION

Having just one copy of BBC Knowledge Magazine isn't enough to go around? Not to worry – Discounts on bulk subscriptions are now available for schools, libraries and organisations who are keen to order more than 50 copies per issue.

For enquiries or to place an order, email to subscribe@media-group.com.sg or call us at +65 6446 6888 today!

BBC Knowledge Magazine, MCI(P) 055/11/2014, ISSN 1793-9836, PPS 1745/01/2013 (022915), is published by Regent Media Pte Ltd under license from Immediate Media Company Bristol Limited. Printer: KHL Printing Co Pte Ltd (197801823M).

BBC Knowledge

HERE'S HOW TO GET IN TOUCH

PHONE
Subscription, editorial and advertising enquiries
Tel: 6446 6888 **Fax:** 6449 9945

EMAIL
Advertising enquiries
sales@regentmedia.sg
Subscription enquiries
subscribe@media-group.com.sg

POST
Subscription, editorial and advertising enquiries
Regent Media Pte Ltd
20 Bedok South Road, Singapore 469277

DISTRIBUTORS

Singapore - Pansing Distribution Pte Ltd
Malaysia - MPH Distributors Sdn Bhd
Indonesia - PT Javabooks Indonesia
Thailand - Asia Books Co., Ltd.
Philippines - Asia/Pacific Circulation Exponents, Inc.
Taiwan - Formosan Magazine Press Inc
Hong Kong/China/Macau - Times Publishing (HK) Ltd

SUBSCRIPTION AGENTS

Singapore - The Learning Craft Pte Ltd, Emit Asia (S) Pte Ltd
Taiwan - JDM Books International Co. Ltd
Malaysia - Worldwide Magazines Services Sdn Bhd

A publication of Regent Media

recycle

mpas
Member of Magazine Publishers Association, Singapore

FIPP
Member of International Federation of the Periodical Press, UK

Snapshot

Winged wonders

With their 50cm wingspans, these are not your typical insects. They are eMotionButterflies, one of the latest creations of German automation company Festo.

Their ultra-light wings are made from carbon rods, covered by a film of blue elastic. Each body includes one battery and two small motors, allowing four minutes of flight between charges.

Infrared cameras track the robots by detecting the position of tiny LEDs attached to each butterfly's body. A central computer monitors these positions, instantaneously updating the butterflies' routes to keep them out of harm's way.

"Nature shows us that even animals that are neither strong nor particularly complex can demonstrate coordinated movement as a collective," says Festo's Dr Heinrich Frontzek. "This does not require intricate programming, but only a limited number of simple rules for avoiding collisions."

According to Festo, the technology in these bots could be used in a "guidance and monitoring system in the factory of the future".

PHOTO: FESTO

Salt seller

The town of Useless Loop is far more productive than its name suggests.

The town is nestled in Western Australia's Shark Bay and is dominated by the strikingly blue evaporative lagoons that are used to harvest vast quantities of salt.

Around 1.3 million tonnes of the stuff is produced each year by evaporating water from an operational area stretching across 87km^2.

"Shark Bay is extremely hot and dry," says Dr John Statton of the University of Western Australia. "High evaporation rates and low rainfall make it ideal for a solar salt mine."

The region's climate and salinity – the seawater is around 50 per cent saltier than in the open ocean – makes it easy to produce salt in huge quantities, while the spotlessness of the water improves its quality.

"Because the environment is so clean and near-pristine, the salt mine is able to extract very high purity salt that commands a premium price," Statton says.

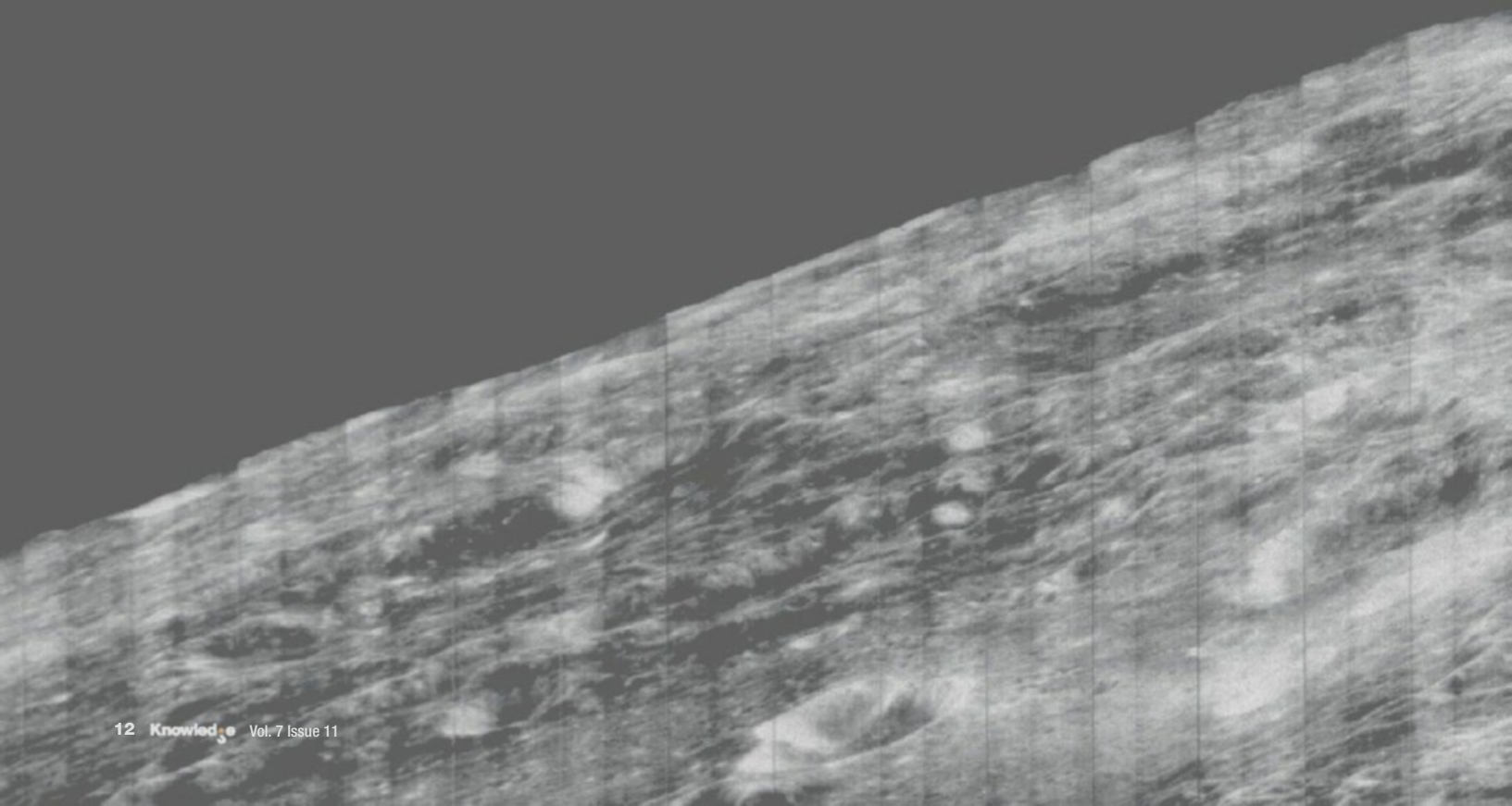
The salt is used for various purposes, including food preservation and the production of caustic soda and chlorine.

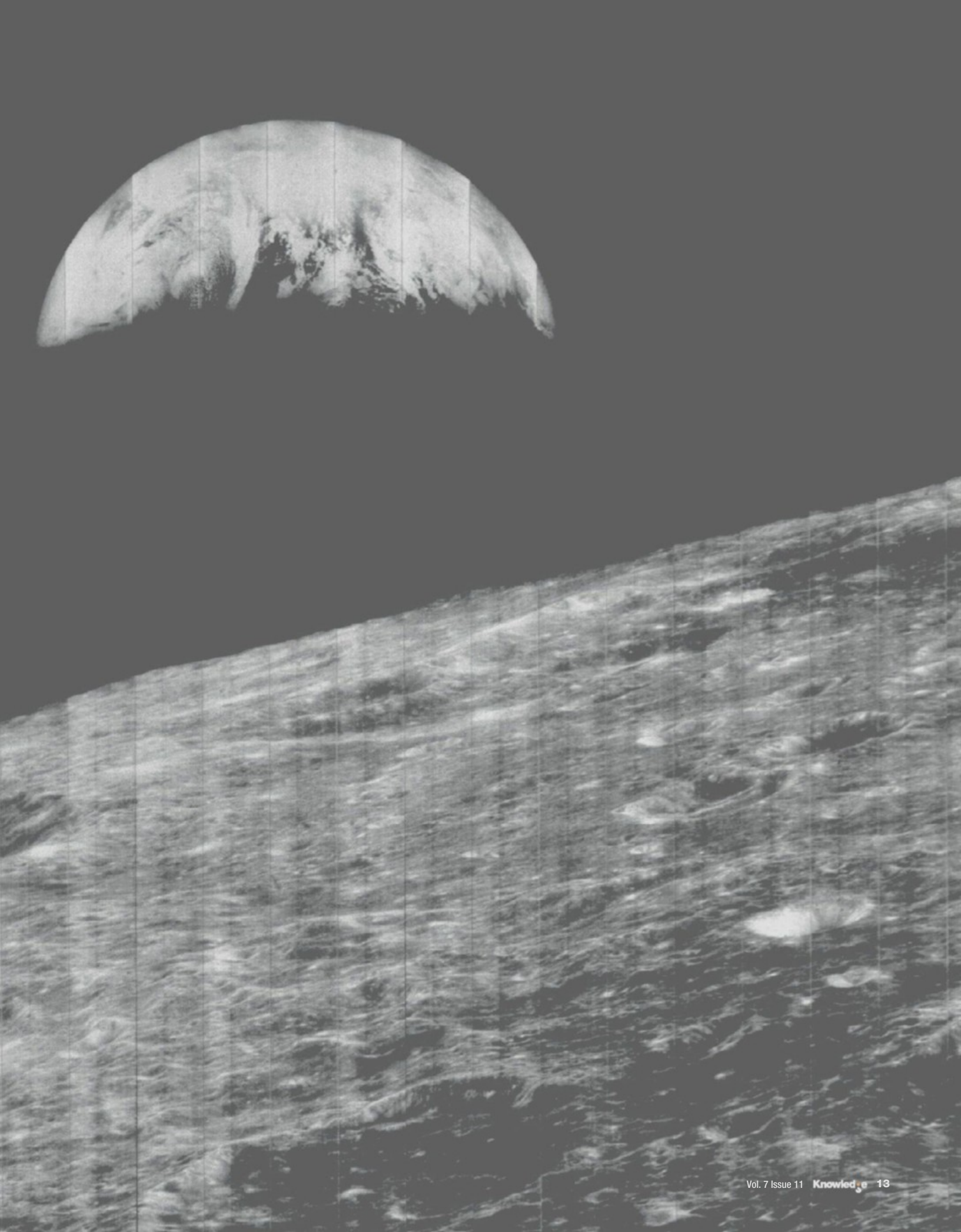
PHOTO: SIMON BUTTERWORTH

First view of Earth

A spacecraft took the World's first view of the Earth from the vicinity of the Moon on October 1st, 1966. The photo was transmitted to Earth by the United States Lunar Orbiter I and received at the NASA tracking station at Robledo de Chavela near Madrid, Spain. This crescent of the Earth was photographed when the spacecraft was on its 16th orbit and just about to pass behind the Moon. This is the view the astronauts had when they came around the rear of the Moon and face the Earth. The Earth is shown with the U.S. East coast in the upper left, southern Europe toward the dark or night side of the Earth, and Antarctica at the bottom of the Earth crescent. The surface of the Moon is shown on the right side of the photograph.

PHOTO: NASA



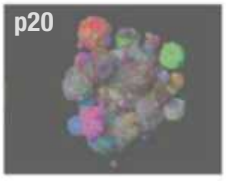


Update

THE LATEST INTELLIGENCE


p17

BOMB-PROOF AEROPLANES
David Shukman goes to see a potentially life-saving new technology in action


p20

BATTLING CANCER
How computer models are shedding new light on tumours


p23

JUNIOR JUPITER
A newly discovered exoplanet could reveal how gas giants are formed

THE BIG STORY

HUMAN TISSUE BUILT CELL-BY-CELL IN THE LAB

Groundbreaking technique is another step towards being able to create replacement human organs on-demand

It's like Lego for scientists: researchers at the University of California have developed a method of turning human cells into 'bricks' that can be assembled into bigger structures such as tissues and organs. The pioneering new technique, dubbed DNA Programmed Assembly of Cells (DPAC), enables researchers to grow 'tissues in a dish' that can be used to study how diseases develop and in drug screening, and may one day be used to build entire functioning human organs.

The human body contains hundreds of different types of cell, with each type playing a unique role in keeping the body's various biological processes running smoothly. The way the cells organise within organs helps them coordinate their functions.

The ultimate aim of DPAC is to build working tissues like this mammary gland

PHOTO: SCIENCE PHOTO LIBRARY

Zev Gartner of the University of California, San Francisco, who led the DPAC research

"Cells aren't lonely little automatons. They communicate through networks to make group decisions," explained researcher Zev Gartner, an associate professor at the University of California, San Francisco (UCSF). "We can take any cell type we want and program just where it goes. We can precisely control who's talking to whom and who's touching whom at the earliest stages. The cells then follow these initially programmed spatial cues to interact, move around, and develop into tissues over time."

Studying how the cells of complex tissues make decisions as groups is incredibly difficult in living organisms, thanks partly to their innate complexity and partly to the associated ethical issues. However, "this technique lets us produce simple components of tissue in a dish that we can easily study and manipulate," said fellow team member and UCSF graduate student Michael Todhunter. "It lets us ask questions about complex human tissues without actually needing to do experiments on humans."

To create the organoids, the team fix tiny snippets of DNA onto the cells' outer membranes. These act as a kind of molecular Velcro that allows one cell to stick to another, provided it has complementary DNA. If the DNA sequences don't match, the cells don't stick. These cells can then be built up in layers to form complete organoids.

So far the team has created tissue that mimics veins, arteries and mammary glands. Next, they plan to use the technique to investigate the breakdown of tissue structure that is associated with tumours which spread and threaten the life of the patient. Ultimately, they hope to upscale their technique to build neural circuits and functional human organs such as lungs and kidneys.

"Building functional models of complex cellular networks such as those in the brain is one of the highest challenges you could aspire to," Todhunter said. "DPAC now makes that lofty goal seem much more achievable."

Timeline
The quest to build human organs in the lab

2006

Anthony Atala and his team at North Carolina's Wake Forest University successfully transplant lab-grown bladders into seven human patients using tissue grafts.

2013

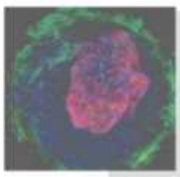
A team at Yokohama University in Japan grows tiny human livers using stem cells. Lab-grown organs may one day reduce our reliance on organ donations.

2014

Scientists at King's College London grow an epidermis, the outer layer of skin, using human stem cells. It could be used in place of animals in drug and cosmetic testing.

2015

Researchers at the University of California make a tiny, beating heart by creating stem cells from human skin cells and manipulating them as they develop.

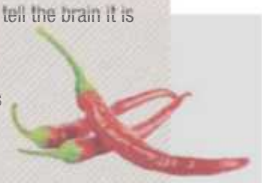


GOOD MONTH/ BAD MONTH

It's been good for:

SPICE LOVERS

Make mine a vindaloo: researchers at the University of Adelaide have discovered that eating spicy food may help to keep you trim. When the stomach stretches after eating, gastric nerves trigger to tell the brain it is full. The process is regulated by the TRPV1 protein, a receptor that's also activated when we eat chilli peppers.



CRYBABIES

Feel like having a good blub? Well, it's better to let it out. Researchers in the Netherlands found that volunteers who cried while watching a weepy movie were in a better spirits that their more stoic counterparts 90 minutes after it finished – despite their mood initially dipping.

It's been bad for:

THE SQUEAKY VOICED

If you fancy becoming a politician you might want to work on deepening your voice, a team at the University of Miami has found. When played two voice clips of a politician asking for votes, one higher pitched and one lower, 75 per cent of the participants chose the latter. The effect may be due to a deeper voice being associated with a high level of testosterone, strength and power. Brian Blessed for PM!

SHORT SLEEPERS

Late nights and early starts are the perfect recipe for catching colds, according to researchers at the University of California. They found that test subjects getting less than six hours sleep a night were 4.2 times more likely to catch the sniffles than those sleeping for seven or more.

PHOTO: ISTOCK, ZHEN MA/UC BERKELEY

ASTRONOMY

Astronomers show that galaxies can change shape

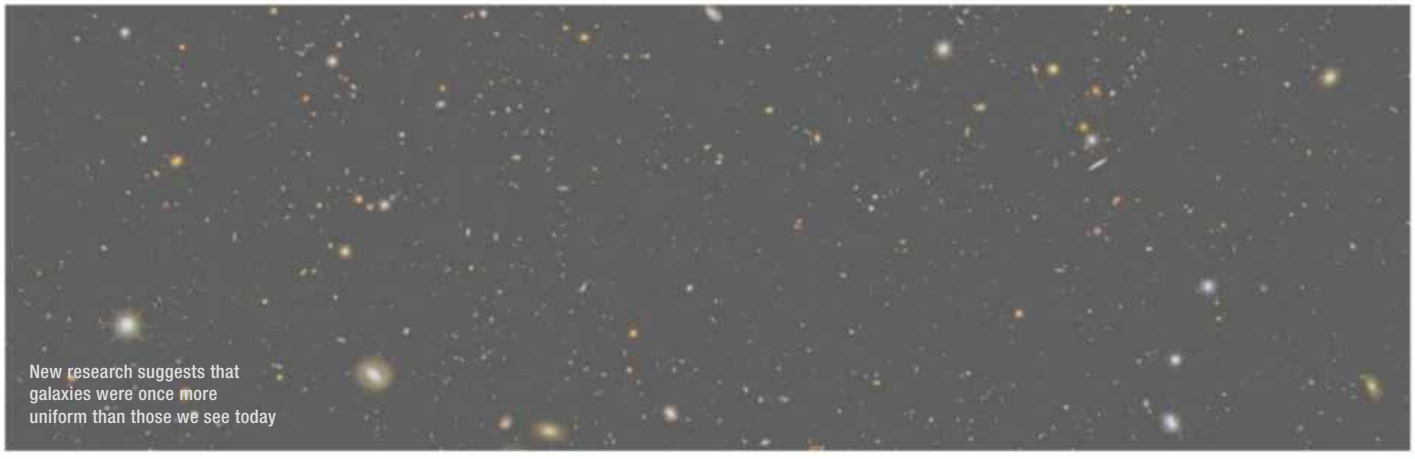
The first evidence that galaxies can change shape has been found by an international team of astronomers led by Prof Steve Eales from Cardiff University's School of Physics and Astronomy.

"Many people have claimed before that this metamorphosis has occurred, but by combining Herschel and Hubble, we have for the first time been able to accurately measure the extent of this transformation," said Eales. His team published their findings in the journal Monthly Notices Of The Royal Astronomical Society in August.

The team were able to do this after making observations of 10,000 galaxies and classifying them into two types: rotating, flat discs (such as the Milky Way) or large, spherical galaxies. Then, using the Hubble and Herschel telescopes to peer at galaxies much further away – and thus much further back in time – the team were able to compare today's galaxies with those formed in the aftermath of the Big Bang.

Eales's team found that 83 per cent of the stars formed immediately after the Big Bang were located in rotating disc galaxies. But today only 49 per cent of stars are found in such galaxies, with the rest found in large, spherical ones, suggesting many galaxies have undergone major transformations during their lifetimes.

One possible cause for such a transformation could be two disc galaxies merging into one another after colliding. But it's also thought there may be cases where stars in a disc galaxy are drawn towards the centre and group together to form a spherical galaxy.



New research suggests that galaxies were once more uniform than those we see today

PSYCHOLOGY

Link between neuroticism and creativity explained

Do you lie awake, fretting over the tiniest of problems? You may be a creative genius!

It's long been known that people who suffer from neurotic thoughts tend to perform better in creativity tests than their calmer counterparts, but now Dr Adam Perkins of King's College London has come up with an explanation as to why.

Previous MRI studies have shown that those who have spontaneous negative thoughts, a key marker of neuroticism, have increased activity in the medial prefrontal cortex, a brain region associated with threat perception. It's also been shown that the amygdala, the brain's emotional centre, acts a switch that controls when an individual goes into 'panic mode'. Perkins believes a combination of high activity in the medial prefrontal cortex and an over-sensitive 'panic switch' gives neurotics an increased tendency to imagine threats when none are present – as well as a highly active imagination that could make them more creative.

"We're still a long way off fully explaining neuroticism, but we hope our new theory will help people make sense of their own experiences, and show that although being highly neurotic is unpleasant, it also has creative benefits," Perkins said.

PHOTO: GETTY, NASA

Can science help protect planes from terrorists?

DAVID SHUKMAN
The science that matters

At a graveyard for old jets, a curious experiment was taking place. At Cotswold Airport near Cirencester, engineers were inside a disused Airbus getting ready for an unusual task: to detonate a bomb.

After years of lab tests, this was the moment of truth for a system, called Fly-Bag2, for resisting explosions onboard an aircraft. Fly-Bag2 consists of four layers of fabric, including bulletproof Kevlar, stitched into the shape of a large box, into which the passengers' luggage is placed.

Cameras were ready as the detonation switch was flicked. As we stood a safe distance away, there was the sound of a muffled boom. The plane itself did not seem to move at all. When the air cleared, we clambered inside the aircraft's hold. The smell of explosive hung in the air. But while some luggage inside the bag was charred, the bag itself – remarkably – was unscathed.

The shockwave, pressure and heat had been overcome by a clever mix of strength and flexibility. The design is the result of materials research and sophisticated modelling at the University of Sheffield and a dozen other European institutions and companies.

Yes, they packed Fly-Bag2 themselves, and no, it hasn't been out of their sight since

The motivation for the project is the risk of another Lockerbie, when a bomb in the luggage of Pan Am flight 103 killed 270 people in the air and on the ground in 1988. Since then, airport security has improved immeasurably and on some routes airlines pay for extra searches, or even bring in their own teams. But the logic of the team behind Fly-Bag2 is that no airport screening can be 100 per cent foolproof, so surely it's better to have a last line of defence.

It's up to the airlines to decide whether to buy the system. It would inevitably add to their costs, and may make tickets more expensive. But watching high-speed video shot at the instant of the explosion is not only impressive but also reassuring: the walls of the bag bulge and billow but, crucially, do not give way.

DAVID SHUKMAN is the BBC's Science Editor. @davidshukmanbbc

Fly-Bag2 could prevent a Lockerbie-style disaster

PHOTOS: MITCH GINSBURG/TIMES OF ISREAL, D'APPOLONIA SPA

WHO'S IN THE NEWS?

Brenda Laster

Radiation biologist and pathologist

Who is she?
A former director of the radiology lab at Israel's Ben-Gurion University of the Negev.

What has she been up to?
She has been ingesting small doses of hydrogen peroxide (H_2O_2), a powerful chemical that's used to make explosives and hair bleach, on a daily basis for the last six years.

Why on Earth is she doing that?
Studies on nuclear disasters such as Chernobyl or Fukushima have found that the bodies of those hit by high doses of radiation produce fatal quantities of hydrogen peroxide. Laster believes she can teach her body to adapt to this.

So she's making herself radiation-proof?
That's the general idea. Lester hopes her daily dose of bleach will let her build up an immunity to the deadly H_2O_2, just as vaccinations grant immunity against viruses.

What has she found?
She hasn't published any results yet, so watch this space. In the meantime, seriously: don't try this at home.

10 DISCOVERIES THAT WILL SHAPE THE FUTURE

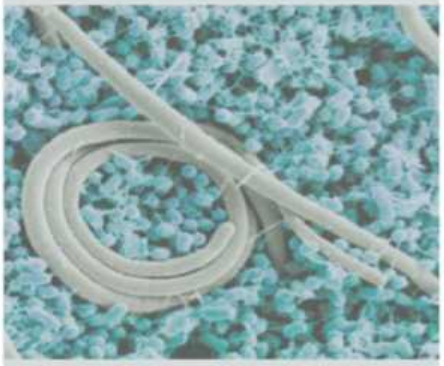
10 A step towards universal flu vaccine

If you hate going for an annual flu jab, there's hope on the horizon. Flu vaccines need to be updated every year to cope with new flu strains, caused by genetic mutations in the influenza virus. But now medics at America's National Institute of Allergy and Infectious Diseases have created a nanoparticle vaccine that targets the part of the virus that mutates the least. Antibodies produced by the vaccine didn't stop mice and ferrets catching flu, but they did prevent most of the animals dying from a normally lethal dose of H5N1 influenza.

Nanoparticles may make the annual flu jab a thing of the past

9 Disease detection

Infectious diseases cause 22 per cent of deaths globally and detecting them quickly is essential to stop them spreading. Currently, outbreaks are monitored by compiling doctors' reports, but carrying out genetic analysis of toilet waste on aircraft could speed things up. By studying waste arriving from both North and South Asia and North America, scientists at the Technical University of Denmark found geographical differences, including more Salmonella enterica in samples from South Asia.



More Salmonella enterica was found in the contents of aeroplane toilets on flights arriving from South Asia

8 The perfect pea

Peas are tasty but they contain protease inhibitors that prevent us from getting all their nutritious proteins. But now scientists at the John Innes Centre have identified wild peas that possess genetic mutations that reduce the effect of these inhibitors.

Mutant peas make getting more nutrition easy peasy

7 New drug helps alcoholics recover

A drug for treating alcoholism without causing depression could be available within five years. Existing treatments target the dopamine release that alcohol triggers in the brain but can leave patients depressed. Now scientists at the University of Wisconsin, Milwaukee have made compounds that reduced both the amount of alcohol drunk by test rats and their anxiety.

New drugs may make it easier to stay on the wagon

6 Making money from CO_2

It seems the perfect solution to climate change: suck carbon dioxide out of the atmosphere and do something useful with it. Scientists at George Washington University have done this by producing carbon nanofibres (below), worth hundreds of times more than the cost of making them, from atmospheric CO_2. They can be used in tennis rackets, turbine blades and even planes.

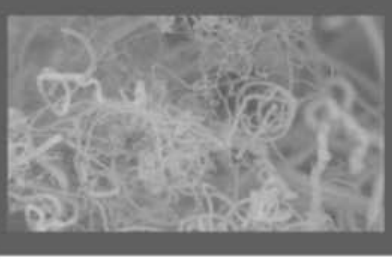


PHOTO: ISTOCK X2, JEAN GUARD/ARS/WIKIPEDIA COMMONS, BENJAMIN LEEVER PH.D, CASEY MANN, ASU/ NATURE NANOTECHNOLOGY, KARSCH/PFEIFFER, STUART LICHT PH.D, JOHN INNES CENTRE

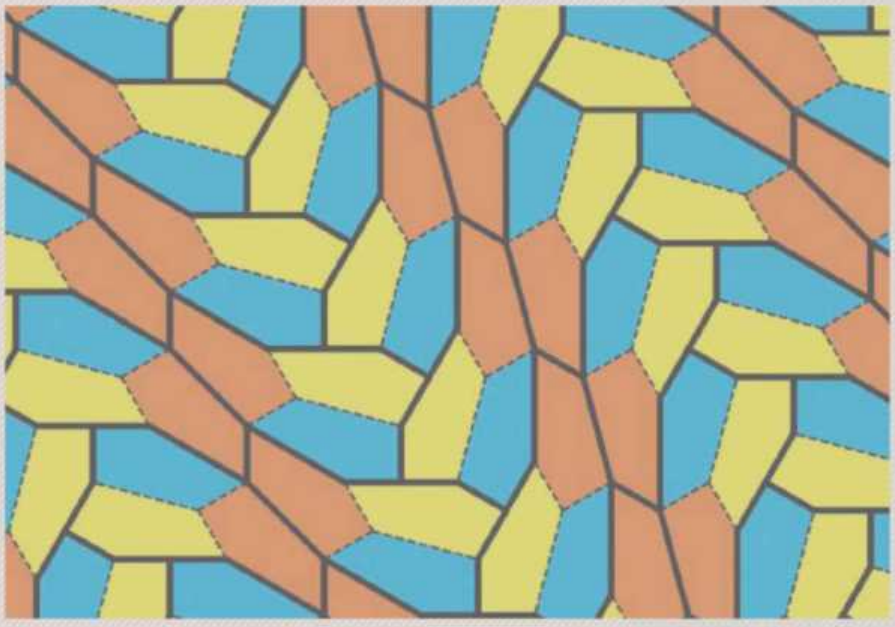
5 DNA ‘hard disks’

If DNA were used in place of hard disks, you could store a staggering 300,000TB in just one gram. The advantage of DNA storage, as demonstrated by a team led by ETH Zurich researcher Robert Grass, is that it can last up to 2,000 years. It’ll be a long time, though, before the technology is cheap enough and ready for the mainstream.

4 Flexible electronics

A patch containing flexible electronic circuitry that measures your pulse is being developed for US Air Force pilots. It could also be adapted to measure mechanical stress in buildings and bridges.

New methods to measure stress are being developed



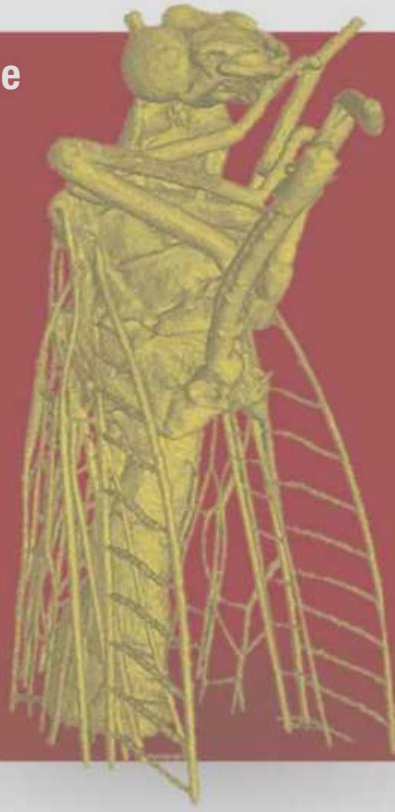
Fancy this pattern for the tiles in your bathroom? It may not be aesthetically pleasing (at least not in these colours) but it is mathematically possible

3 Practical pentagon

Much as you might like to, you can’t tile your bathroom using any shapes with more than six sides - it’s mathematically impossible. But finding useable shapes with five sides isn’t easy either. A shape just discovered at the University of Washington is only the 15th pentagon capable of doing it – and is the first to be found in 30 years. As well as tiling, it could have practical uses in architecture and drug design, in which new compounds are created from chemical building blocks.

2 Laser X-rays save money and lives

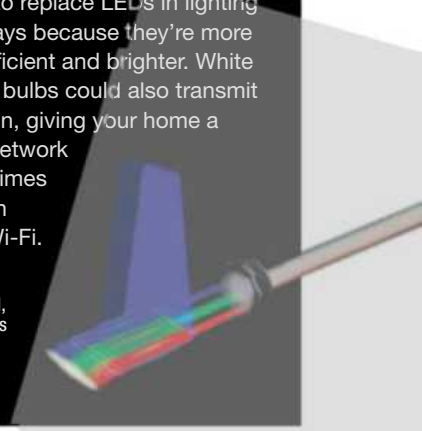
A new kind of X-ray technique may one day be able to reveal small cancerous tumours before they have the chance to spread through the body. Cancerous tissue is less dense than healthy tissue – a difference the new method can detect. Researchers at the Max Planck Institute of Quantum Optics tested it by making a highly detailed 3D image of a small fly. Unlike similar images produced using huge particle accelerators, the new technique is cheaper as it uses X-rays generated by a laser.



The imaging technique used to create this image of a fly could be adapted to detect cancerous growths

1 White lasers

Red and green lasers are nothing new. Now, Arizona State University scientists have combined red, green and blue beams to create the world’s first white laser. In time, white lasers are likely to replace LEDs in lighting and displays because they’re more energy-efficient and brighter. White laser light bulbs could also transmit information, giving your home a wireless network that’s 10 times faster than existing Wi-Fi.



Combining red, blue and lasers creates an energy-efficient white beam

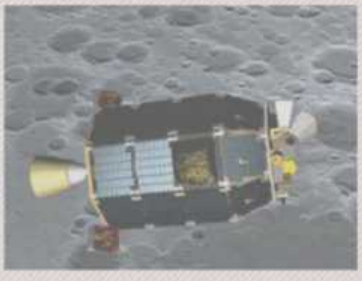
1 MINUTE EXPERT
The lunar atmosphere

The Moon has an atmosphere?
Yep. NASA's LADEE craft has detected abundant levels of neon in the lunar atmosphere, which means we now know that it is mostly made up of neon, helium and argon.

Where does it come from?
Solar wind shoots into space from the Sun, and this gassy breeze containing hydrogen, helium and small volumes of other gases hits the surface of the Moon. Only helium, argon and neon are volatile enough to bounce back and enter the atmosphere, while the other gases stay on the surface.

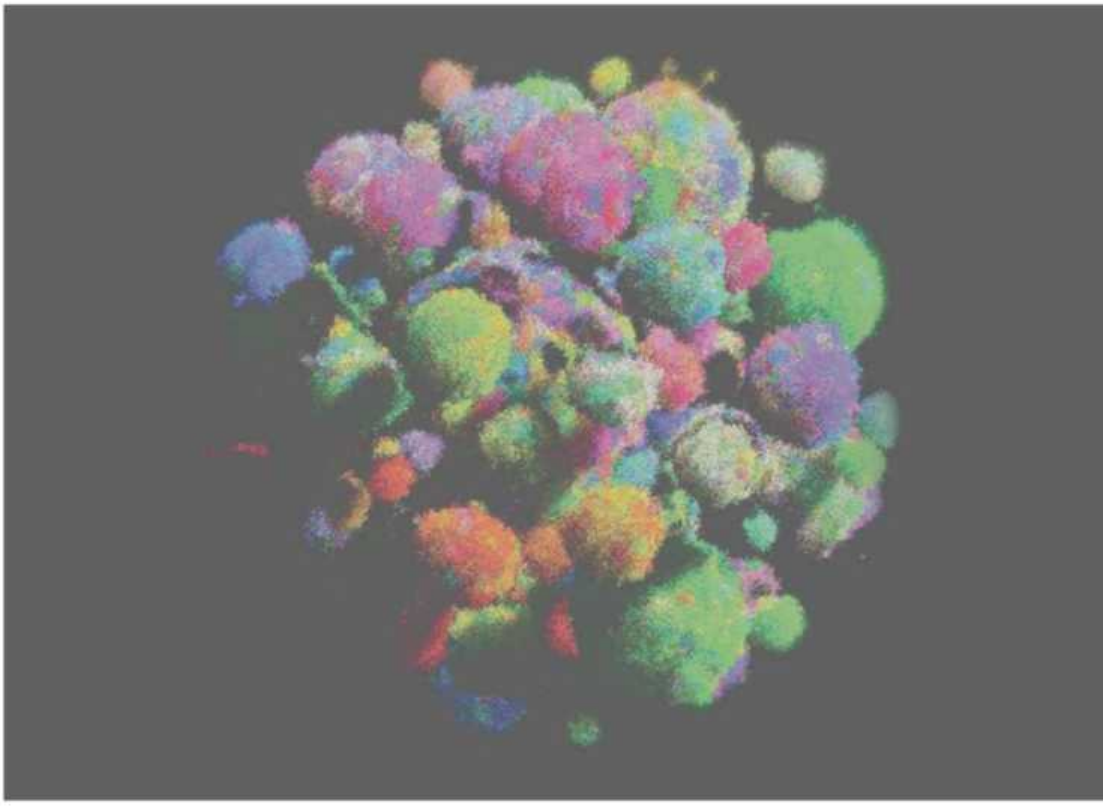
Can it get all that from solar wind?
The atmospheric gases are mostly provided by solar wind, but the Moon itself also has its own supply of gases. Argon-40 is released from the radioactive decay of potassium-40 and helium from the decay of thorium and uranium, elements that are found in lunar rocks.

So is that why the Moon glows?
No, although neon is used to make bright nightclub signs here on Earth, the Moon's atmosphere is so thin that there is not enough neon to produce a glow. In fact, the Moon's atmosphere is 100 trillion times less dense than ours. The light that we see when we look up at the Moon has been reflected from the Sun.



NASA's LADEE spacecraft orbited the Moon from October 2013 until April 2014

PHOTO: BARTEK WACLAW AND MARTIN NOWAK, ISTOCK, THOTH TECHNOLOGY INC, SKYWORKS/NASA



MEDICINE

Cancer modelled in 3D for first time

It may look like a bunch of colourful pom-poms to the untrained eye, but this 3D computer model of a tumour may help researchers to develop more effective treatments for cancer.

The model was developed by an international team of scientists working at Harvard, Edinburgh and Johns Hopkins universities, and is the first that accurately portrays a tumour's 3D structure as well as its genetic evolution, with each different colour in the model representing a different mutation.

Cancer develops when the genes in a cell mutate and begin multiplying uncontrollably. If a mutated cell multiplies enough times, it can create a large clump of abnormal cells – a tumour.

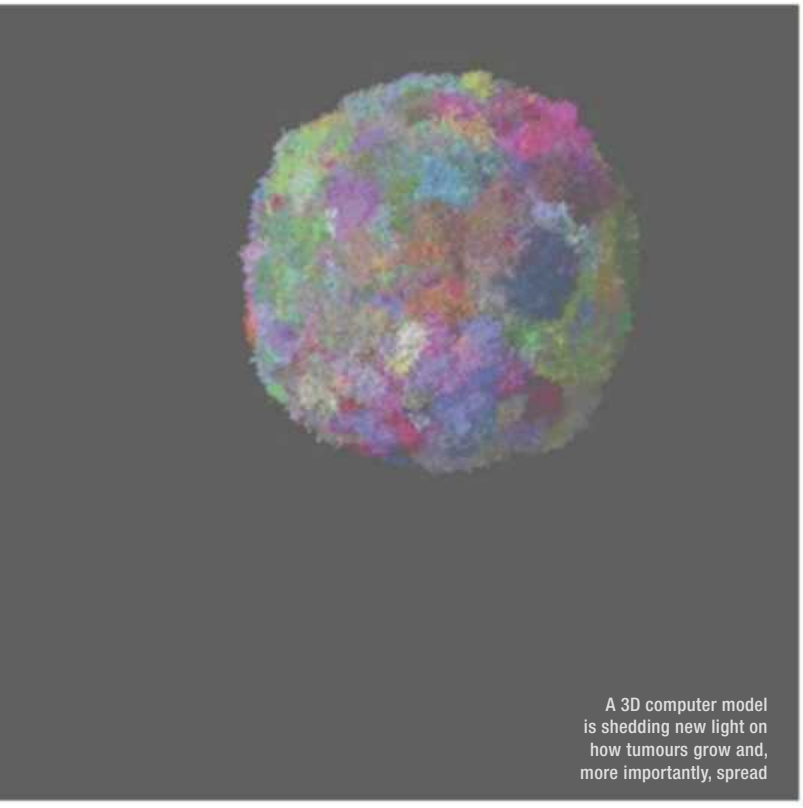
All cells accumulate mutations as they divide. Most are known as 'passenger' mutations and have little effect. In cancer cells, however, around 5 per cent of mutations allow cells to divide faster or live longer. These are known as 'driver' mutations. The model visualises how tumours grow over time and provides a key insight into the cells' ability to migrate away from the

THEY DID WHAT?!
Biologists engineer 'brainy mice'

What did they do?
A University of Leeds team, led by Dr Steve Clapcote, altered a gene in mice that inhibited the activity of an enzyme called phosphodiesterase-4B (PDE4B), which is present in many organs, including the brain. They studied the effect this had on the mice's memories and problem-solving skills.

What did they find?
Compared to normal mice, the PDE4B-inhibited mice learned faster, remembered things for longer and performed better at problem-solving. They also appeared to be less affected by scary experiences than unaltered mice, and spent less time cowering in corners.

Why did the scientists do that?
As PDE4B is also present in human



A 3D computer model is shedding new light on how tumours grow and, more importantly, spread

tumour and ultimately move to other places in the body in a process known as metastasis.

"Cellular mobility makes cancers grow fast, and it makes cancers homogenous in the sense that cancer cells share a common set of mutations," said Harvard's Martin Nowak, who led the research. "I further believe that the ability to form metastases, which is what actually kills patients, is a consequence of selection for local migration."

Driver mutations also play a role in drug resistance. If a small number of cells are resistant to a therapy, they can quickly replicate, causing a relapse of the cancer even if nearly all of the other cancerous cells are wiped out.

"Our approach does not provide a miraculous cure for cancer," said the University of Edinburgh's Bartek Waclaw, who was also involved in creating the new 3D model. "However, it suggests possible ways of improving cancer therapy. One of them could be targeting local cellular migration and not just growth, as standard therapies do."

brains, the work may help to shed light on the molecular mechanisms of learning and memory. Further down the line, it could also form the basis for further research into treatments for age-related cognitive impairment and cognitive disorders, such as Alzheimer's disease and schizophrenia.

This little chap has memorised Pi to over 17,500 decimal place

PATENTLY OBVIOUS with James Lloyd

Inventions and discoveries that will change the world

Fruity tattoos

For those who want a tattoo, but aren't quite ready to be permanently inked, how about one that lasts for two weeks? Unlike other temporary tats, Inkbox's designs last for more than just a few days. The secret lies in a fruit-based formula that stains the top layer of skin (the epidermis) but, unlike conventional tattoos, not the layer beneath (the dermis). Place the adhesive stencil on the skin, hold a wet cloth over it for 10 minutes, and wait 24 hours for the tattoo to appear. Hipster heaven!

Patent pending

Diet dressing

Imagine if losing weight was as easy as changing your clothes. That's the bold claim of Adam Paulin, creator of Thin Ice clothing. His insoles and vests are embedded with cooling chips – essentially miniature heat pumps – that chill specific areas of the body. This localised cooling tricks the body into thinking it's in a cold environment, sending the metabolism into overdrive and burning off fat in the process. The makers say that the cold sensation disappears after a few seconds.

Patent pending

Stairway to heaven

Space elevators are the stuff of sci-fi dreams, taking astronauts into space without the need for fuel-guzzling rockets. But there's one big problem: how do you build a structure tall enough, that's also strong enough to support its own weight?

Canadian space company Thoth Technology thinks it has a solution. It has patented a freestanding space tower that's composed of a series of pneumatic pressure cells. Each of these cells, made from a high-strength material such as Kevlar, is filled with pressurised gas, keeping the structure rigid as it gets buffeted by winds.

Reaching 20km (12 miles) into the sky, the elevator wouldn't take astronauts directly into orbit. Instead, it'd be used as a takeoff and landing pad for single-stage space planes, which Thoth claims will save more than 30 per cent of the fuel when compared to conventional rockets. The electrical elevator could also ferry scientists and tourists back and forth. Beats a trip to Magaluf, anyway…

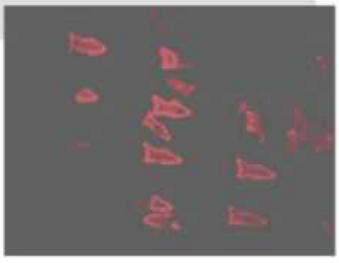
Patent number: US 9,085,897

Thoth's space elevator would be a landing pad on a very tall pillar

NANOTECHNOLOGY

Here to help: tiny 3D-printed robot fish

The next time you get sick, your illness may be treated by a school of tiny 'microfish'. A team at the University of California has created 3D-printed fish-shaped microrobots that are capable of swimming through liquid and carrying payloads. They could be used for removing toxins or delivering drugs to specific areas of the body.



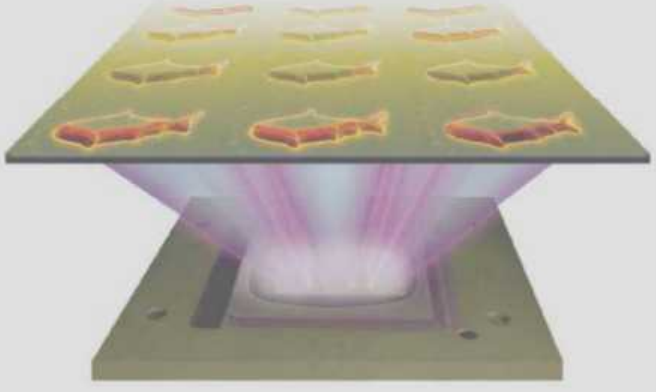
The PDA-laden robotic fish glowed red as they removed toxins from a solution

The bots measure just 120 microns by 30 microns and were printed using a technique called 'microscale continuous optical printing', in which UV light is shined onto a photosensitive material, causing it to solidify. They are built up one layer at a time. This process allows various nanoparticles to be inserted into specific areas to give them specific properties. Platinum nanoparticles in their tails propelled them through a solution of hydrogen peroxide in which they were tested, and iron oxide in their heads allowed them to be steered using magnets. The whole process takes seconds and doesn't rely on the use of harmful chemicals.

"We have developed an entirely new method to engineer nature-inspired microscopic swimmers that have complex geometric structures and are smaller than the width of a human hair. With this method, we can easily integrate different functions inside these tiny robotic swimmers," said researcher Wei Zhu.

To test their concept, the team printed fish embedded with toxin-eating polydiacetylene (PDA) nanoparticles and plunged them into a toxic solution. As PDA fluoresces red when it binds with toxins, the team was able to monitor the bots' detoxification ability by the intensity of the red glow.

"This method has made it easier for us to test different designs for these microrobots and to try out different nanoparticles to insert new functional elements into these tiny structures. It's my personal hope to further this research to eventually develop surgical microrobots that operate more safely and with more precision," said researcher Jinxing Li.



The 'fish' are created using a technique called microscale continuous optical printing and can be customised for a variety of different medical applications

PHOTOS: J.WARNER/W.ZHU & J.LI/UC SAN DIEGO JACOBS SCHOOL OF ENGINEERING, GETTY

ASTROBIOLOGY

Did life on Earth come from comets?

Comets are an impressive sight, but we might owe our very existence to them

The mere mention of comets crashing into the Earth is likely to bring to mind images of mass extinction and the end of days. But researchers at the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) have found further evidence that comet impact may have been vital for the creation of life as we know it.

The team ran a series of experiments aimed at mimicking the kind of comet impacts that are likely to have occurred on Earth at the time when life first appeared, around four billion years ago. They made a mixture of amino acids (the so-called 'building blocks' of life), ice and forsterite, a mineral often found in meteorites. They then cooled it to 77°K and bombarded it with a propellant gun, to simulate the force of a comet impact.

Analysis of the resulting mixture showed that a number of the amino acids had joined together into short chains called peptides. "This finding indicates that comet impacts almost certainly played an important role in delivering the seeds of life to the early Earth," said Haruna Sugahara, who was lead author of the study.

"The production of short peptides is a key step in the chemical evolution of complex molecules. Once the process is kick-started, then much less energy is needed to make longer chain peptides in a terrestrial, aquatic environment." The work also suggests that the same process could have occurred on other planets and other extraterrestrial bodies.

"Within our own Solar System, the icy satellites of Jupiter and Saturn such as Europa and Enceladus are likely to have undergone a similar comet bombardment. The NASA stardust mission has shown the presence of the amino acid glycine in comets," Sugahara added.

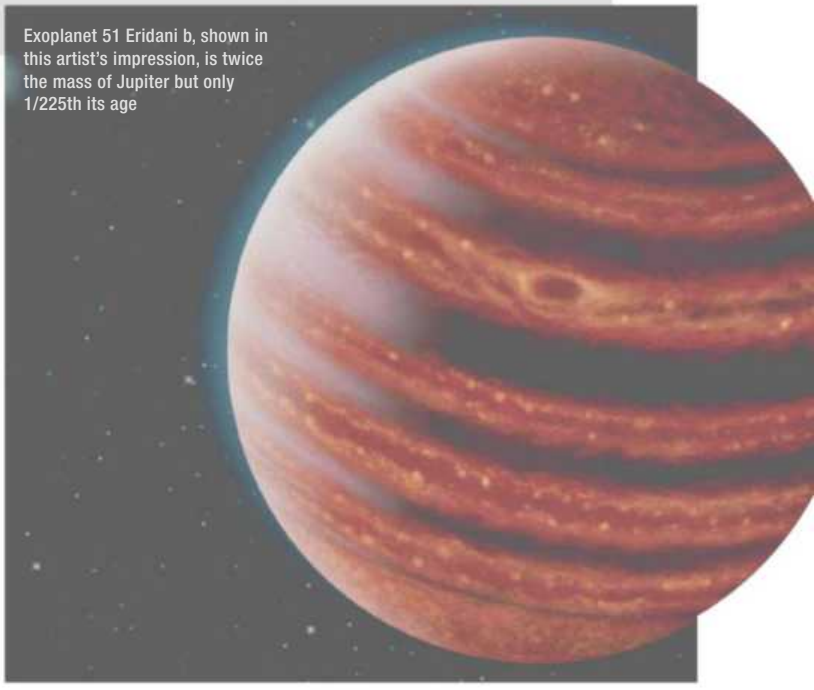
ASTRONOMY

Exoplanet could shed light on birth of the Solar System

Say hello to 51 Eridani b, the 'younger cousin' of Jupiter that may help scientists figure out how our Solar System was formed. The exoplanet was spotted orbiting a young star 100 light-years away by the Gemini Planet Imager (GPI), a planet-hunting instrument installed on Chile's Gemini South Telescope. It's roughly twice the mass of Jupiter, with a surface temperature of around 430°C and an atmosphere rich in methane. The planetary system it inhabits is just 20 million years old, much younger than our own 4.5-billion-year-old Solar System, and could provide clues as to what Jupiter looked like in its infancy.

"In the atmospheres of the cold giant planets of our Solar System, carbon is found as methane, unlike most exoplanets, where carbon has mostly been found in the form of carbon monoxide," said Mark Marley, of NASA Ames Research Center. "Since the atmosphere of 51 Eridani b is also methane-rich, it signifies that this planet is well on its way to becoming a cousin of our own Jupiter."

Astronomers believe that the gas giants in our Solar System, such as Jupiter and Saturn, formed by first gathering up a large core of heavy elements over the course of millions of years, which then pulled in vast quantities of surrounding hydrogen and other gases to form an atmosphere. However, the Jupiter-like exoplanets so far discovered don't fit with the predictions of current models. Further study of young planets such as 51 Eridani b may help to explain why this is.



Exoplanet 51 Eridani b, shown in this artist's impression, is twice the mass of Jupiter but only 1/225th its age

BIOLOGY

Ageing process 'turned off' in worms

Those nematode worms not busy being born are busy dying

Could a 'gentic switch' be the key to eternal youth? Researchers at Northwestern University in Illinois, USA have found that turning off specific genetic processes triggered in early adulthood effectively halted the ageing process in nematode worms. The same mechanism is also seen in other animals, including humans.

Further study could lead to therapies to provide humans with an improved cellular quality of life, and so delay diseases related to ageing, such as neurodegenerative diseases. "Wouldn't it be better for society if people could be healthy and productive for longer during their lifetime?" says researcher Richard I Morimoto. "I'm very interested in keeping the quality control systems optimal as long as we can, and now we have a target. Our findings suggest there should be a way to turn this switch back on, and protect our ageing cells by increasing their ability to resist stress."

In Caenorhabditis elegans, a type of nematode worm, the ageing process begins just eight hours after the animal reaches adulthood. Stem cells responsible for making eggs and sperm flick a genetic switch that shuts off mechanisms which protect cells from stress. Once the stem cells have completed their job and produced eggs and sperm to create the next generation of animals, they send a signal to cell tissues to turn off the protective mechanisms, starting the decline of the adult animal.

"C. elegans has told us that ageing is not a continuum of various events, as many people thought it was," Morimoto says.

PHOTOS: J.WARNER/WZHU & J.LI/UC SAN DIEGO JACOBS SCHOOL OF ENGINEERING, GETTY

BIOLOGY

Cutting-edge imaging reveals inner workings of cells

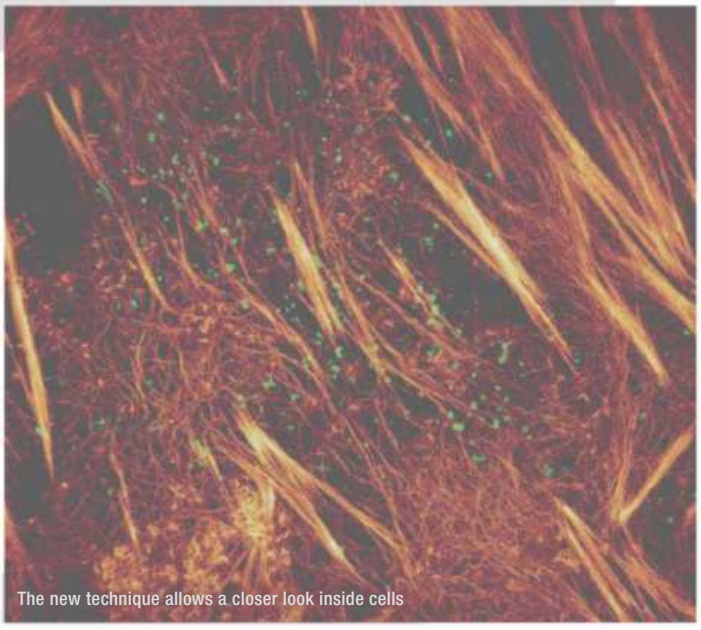
Have you ever wondered what's going on inside a cell? Well, now you can see for yourself. Researchers at the Howard Hughes Medical Institute have shot stunning 'movies' that capture biological processes as they occur within living cells.

To produce the videos, the team, led by Nobel laureate Eric Betzig, made refinements to an existing technique called structured illumination microscopy (SIM). In regular SIM, the sample being imaged is illuminated by several different patterns of light. The reflections from the patterns are captured from a number of different angles and then combined to form a 3D image by computer software. This enables the technique to produce images with twice the spatial resolution of traditional light microscopy.

However, prolonged light exposure can damage cells. To overcome this, the team periodically illuminated small sections of the sample at different times rather than the whole thing all of the time.

"These methods set a new standard for how far you can push the speed and non-invasiveness of super-resolution imaging," says Betzig. "This will bring super-resolution to live-cell imaging for real."

They used the technique to show the action of proteins in muscles during contractions, and in a functioning kidney.



The new technique allows a closer look inside cells

EVOLUTION

Giant sea scorpion fossil discovered

You wouldn't want to bump into this guy when you were out for a leisurely swim! Palaeontologists at Yale University have discovered fossils belonging to a giant predatory sea scorpion.

Dubbed Pentecopterus decorahensis, thanks to its resemblance in shape to the ancient Greek warship known as a penteconter, the animal could grow to almost two metres in length and had a heavily armoured head and large, grasping limbs for trapping prey.

The creature lived around 467 million years ago, making it the oldest eurypterid – a group of aquatic arthropods that were the ancestors of modern spiders, lobsters and ticks – discovered to date. Researchers say that it is likely to have lived in shallow, brackish water with a low salt content that would have been inhospitable to more typical marine animals.

"This discovery shows that eurypterids evolved some 10 million years earlier than we thought, and the relationship of the new animal to other eurypterids shows that they must have been very diverse during this early time of their evolution, even though they are very rare in the fossil record," said James Lamsdell, a post-doctoral geologist who was lead author of the study, which was published in the journal BMC Evolutionary Biology.

The fossils were unearthed in a flooded meteorite crater near to the Upper Iowa River in northeastern Iowa, USA. Both adult and juvenile Pentecopterus decorahensis specimens were found, giving the researchers a wealth of information about the animal's physiology and development. The lack of oxygen in the crater has also meant that the fossils are incredibly well preserved.

Too cute to add to paella?

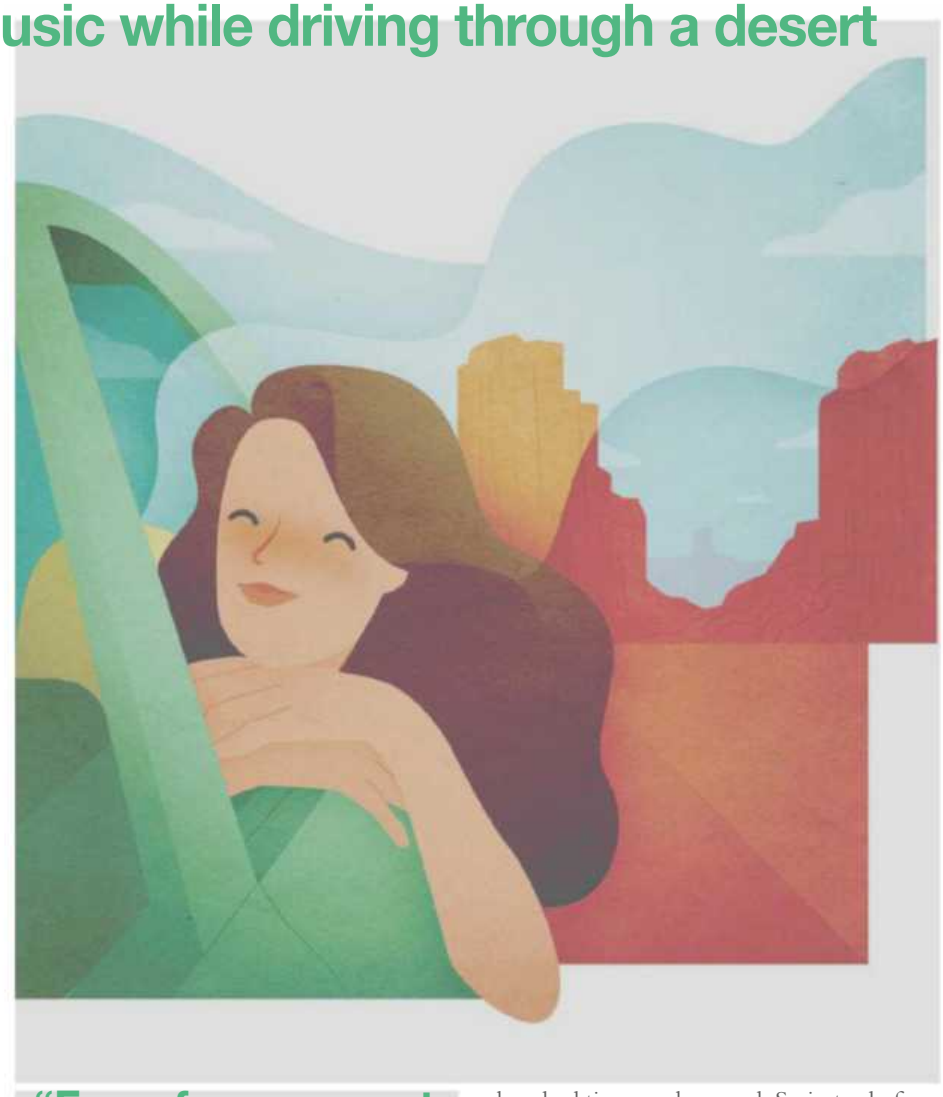
How to make music while driving through a desert

We were driving through a stark and stunning landscape at dusk, still 80km (50 miles) from the location for the next day's documentary filming. The final orange glow of the sunset was picking out specific rocks so that they seemed to be on fire. Rob, our cameraman, could barely contain his excitement at the aesthetic smorgasboard whooshing past. Alex, the director, was at the wheel and worried about being late. He agreed that it was fabulous but said that we had no time to stop to film it. I laughed at Alex for being the strict schoolmaster, but the next rock was too much for Rob. He wound down his window a little way to take photos.

Immediately, a loud and low-pitched regular thumping filled the car. The whoomph-like noise was hammering on our ears and was pretty uncomfortable to listen to. Alex made a face, mustered his stoicism, and then after a few moments it occurred to him to open the driver's window just a tiny bit. The noise stopped. Rob happily snapped away, and then wound his window up. But I was excited and wanted to hear this strange sound again. Alex closed his eyes briefly, shook his head and braced himself. 'Whoomph, whoomph, whoomph…'

The reason that I was excited is that you don't often get to feel as though you're inside a musical instrument. I was imagining the air in the car being shunted about around me. When the first window was opened, the car turned into a rigid air-filled container with just one small opening to the outside. As the wind rushed past the window, it jostled the air molecules just inside, shoving on them and squashing the contained air slightly.

If you squeeze a balloon, it pushes back, and that's what was happening in the car. The squeezed air in the car started to push back out, slightly overshooting the window into the outside. And then the rushing wind on the outside pushed it back again. A regular pulsation was set up: air was pushed in and then it pushed back. We heard one 'whoomph' on each cycle. This effect is known as a 'Helmholtz resonance'. The air in a bigger container will pulsate at a slower rate, because it takes a long time to be squashed and to push back. In our car, there were between one and two pulsations each second.



"For a few moments we felt as though we were sitting in the guts of a musical instrument, one being played by the wind"

When somebody blows across the top of a beer bottle, exactly the same thing happens. The note that you hear comes from the air inside the bottle pushing on the outside air, making a single note at the frequency of the air pulsating in and out of the bottle. But because the beer bottle is smaller, the pulsation happens much more quickly, perhaps a few hundred times each second. So instead of hearing all the individual thumping noises that there are on the inside, you just hear a single note at the frequency of the pulsations.

Back to the car. The trick Alex used to make the sound go away, opening a second window, spoils the setup. In this scenario the container now has two holes on opposite sides, so if you shove air into one, it's just pushed out of the other one. It's not squashed, so it can't push back, and there is no pulsation. While the noise in the car was a bit uncomfortable to listen to, it was worth it for a few moments to feel as though we were sitting in the guts of a musical instrument, one being played by the wind as the desert rushed by. ■

DR HELEN CZERSKI is a physicist, oceanographer and BBC science presenter whose most recent series was *Super Senses*

ILLUSTRATOR: ANDREW LYONS

4 EASY WAYS TO SUBSCRIBE:

GO ONLINE*
e-SHOPPING.SG

OR EMAIL
subscribe@
media-group.com.sg

FAX TO
SINGAPORE
65-6449 9945

MALAYSIA
603-42926251

CALL HOTLINE
SINGAPORE
65-6446 6888

MALAYSIA
603-79548989

BBC KNOWLEDGE MAGAZINE SUBSCRIPTION OFFER

YES! I WANT TO SUBSCRIBE!

SPECIAL SUBSCRIPTION OFFER!

GREAT REASONS TO SUBSCRIBE

- Every issue delivered direct to your door
- Exclusive subscriber-only offers and discounts

MAIL TO
Regent Media Pte Ltd, 20 Bedok South Road, Singapore 469277
or
Unit 6.02 Level 6, Menara Maxisegar
Jalan Pandan Indah 4/2 Pandan Indah
55100 Kuala Lumpur.

PLEASE TICK ACCORDINGLY

❍ Singapore, 1 year subscription, 12 issues for S$77

❍ Malaysia, 1 year subscription, 12 issues for RM160

***Rates are inclusive of postage in SGP and MY**

PERSONAL PARTICULARS

Title _____ Surname _____

Name _____

NRIC _____ DOB _____

Tel Number _____ Mobile _____

Email _____

Address _____

Country _____ Postal Code _____

MY PROFILE

Gender	Age Group	Occupation	Annual Income
❍ Male	❍ Below 30	❍ Executive	❍ Below $50,000
❍ Female	❍ 31 - 40	❍ Management	❍ $50,001 - $100,000
	❍ 41 - 50	❍ Professional	❍ $100,001 - $150,000
	❍ Above 50	❍ Businessman	❍ Above $150,000

YOUR PAYMENT OPTIONS

❍ CHEQUE

Please enclose a cheque made payable to:
Singapore: Regent Media Pte Ltd
Malaysia: Regent Media Sdn Bhd

Cheque No.: _____

Amount: _____

❍ CREDIT CARD* (VISA & MASTERCARD ONLY) **Singapore only*

Debited amount under"Golf Events and Marketing" will be reflected in your credit card statement for subscribers in Singapore.

Name on Credit Card: _____

Credit Card No.: _____

Expiry Date: _____

Amount: _____

Signature: _____ Date: _____

TERMS & CONDITIONS:
- This subscription offer is non-refundable
- Promotion is valid till the end of November 2015
- Subscription gifts where applicable are available on a while stocks last basis
- The above subscription rates are only applicable to readers residing in Singapore & Malaysia
- Gifts must be taken as provided and are neither transferable nor exchangeable for cash
- Company reserves the right to replace gift when stock is unavailable
- All prices are inclusive of GST and taxes
- Please allow 4-6 weeks for processing
- Subscribers/Winners will be notified by post
- Subscription gifts/lucky draw prizes are to be collected at address stated on notification letter
- Other terms and conditions apply

PHOTO: GRÉGOIRE BOUGUEREAU

THE HUNT

From the executive producer of Planet Earth and Frozen Planet comes a stunning new series that explores the dramatic world of predation as never before

A last second leap saves a Thomson's gazelle from a cheetah's trip. Cheetahs are the fastest land animals on the planet, reaching top speeds of almost 60mph when chasing their prey. However, the success or failure of a hunt is determined both by the cheetah's speed, and also by how well it can match the twists and turns of its prey; this one has been out maneuvered

A large male lion – Africa's most heavyweight predator. This animal was photographed on location but under controlled conditions

Scan this QR Code for the audio reader

The contests between predators and prey are the most critical events in nature. The outcome of these interactions is seldom a foregone conclusion. For both sides, it is a matter of life and death. This series takes an intimate look at the remarkable strategies of hunters and, in some cases, the hunted, exploring the challenges animals face and the tactics they employ. It is how animals respond to a particular challenge that determines whether they are successful. Predators must not only overcome the significant defences of their prey but also the unique challenges of their habitats. How do you get close to your prey on the open plain, where there's nowhere to hide? How do you even find your prey when you live in a thick forest? How do you cope when the world beneath your feet melts away every summer as it does in the Arctic?

The strategies of both predators and prey are shaped by where they live, so each episode focuses on one principal habitat, whether savannah, jungle or ocean. Stories range from the desert lions that use the cloak of a sea mist to ambush oryx to the killer whales that use teamwork and sonar to pinpoint prey in the open ocean, from the spider that alters its hunting strategy to match its prey to the octopus that walks across land to reach fish trapped in rock pools. Survival depends on many skills – speed, stealth, stamina, strength, ingenuity, and teamwork – but it's how these are applied that makes the difference between success and failure, life and death.

Confident and cinematic in style, The Hunt is a celebration of nature's most determined, specialized and cunning predators and their equally cunning and elusive prey. It combines the epic landscapes of Planet Earth with intimate, engaging behaviour.

The Hunt's Executive Producer Alastair Fothergill

The most exciting behaviour in the natural world is predation, but it has always been portrayed in the same way on screen: bloody teeth, marauding sharks, nature red in tooth and claw. Predators have always been perceived as impressive but aggressive animals, and in particular the kill has been the thing - in the past if you sent a crew out to film a predation sequence, the first thing that the Executive Producer would ask the director is, "Did you get the kill?"

Yet actually the kill itself isn't interesting, because once animals have killed, the story's over. What is interesting is the build up, the strategies adopted by both the predators and prey. This has never been looked at in detail, and that is the aim of The Hunt.

In my previous series Blue Planet, Planet Earth and Frozen Planet, we have looked at habitats, attempting to give the viewer a sense of place or landscape. The Hunt is about a behaviour – predation - but if you think of the challenges that predators and prey face, they're absolutely related to their habitat. And so in The Hunt we have tried to mix the epic landscape photography and sense of environment that people loved in Planet Earth and in Frozen Planet with the best and the most exciting behaviour in the natural world.

How do you get close to your prey on the open plain, where there's nowhere to hide? How do you even find your prey when you live in a thick forest?

One other thing that has emerged through filming the series that has excited me - and I hadn't predicted would happen - is that we've found we have been able to put the audience right in amongst the animals. A lot of wildlife photography is dominated by technology - there's a whole school of wildlife films about using the camera and where that camera is. I personally am not interested in that because I don't want the cameras to get between the audience, the animals and the experience.

Instead, what we've tried to achieve is a sense of being right alongside them as they hunt or are hunted. We have

BELOW: A cheetah must stalk within just 30 meters of its prey undetected, before it starts its sprint.

Pack hunters – African wild dogs have incredible stamina, they work by chasing down their prey over long distances. As one lead dog tires another will take over. The kill is made together and the food is shared amongst the pack.

PHOTO: ELLEN HUSAIN

put gyro-stabilised cameras on elephants, four wheel drives and helicopters so that we have been able to film whole sequences from several different angles with the camera always moving, keeping us up with the hunt, right in the thick of it yet not disturbing the animals.

What I hope will become apparent is this: predators usually fail. People don't realise how hard it is. We want the audience to engage in this real-life drama. I hope they will come away thinking that predators and their prey are all amazing, hard-working animals, exquisitely beautiful, perfectly evolved, trying to solve life-or-death problems, taking on momentous tasks. There are no heroes or villains. The point is, you never know if they will succeed: in the hunt, the outcome is never certain.

Interview with Series Producer Huw Cordey

What sets The Hunt apart from other series that you've worked on?

The Hunt sits in the tradition of other blue chip landmark series like Planet Earth and Frozen Planet but what sets this series apart is its detailed focus on a particular group of animals. There has never been a landmark series that has tackled the subject in this way before, really honing in on the strategies behind predation and evasion. But it's not just about behaviour - to truly understand predators you also need to understand the habitats in which they live because it's the latter that shapes each hunter's strategy. So, The Hunt combines great behaviour with a sense of place.

Every landmark wildlife series must push the boundaries of the genre and The Hunt certainly does that - this is natural history meets drama!

The Hunt is all about strategies, which animals impressed you the most?

It's difficult not to be impressed by all the animals that we filmed - each has something special, whether it's the intelligence of killer whales, the patience of Nile Crocodiles, the ingenuity of a Portia jumping spider, or the stamina of wild dogs. However, the animal that probably captured my imagination more than any other was the leopard. These cats are the masters of stealth - you could walk past one sitting in light cover and you wouldn't even know it was there. But since they don't have stamina or huge amounts of speed they need to get to within 4 metres of their target to have any hope of success. That is quite a skill – though not easy, which is why only 1 in 6 leopard hunts succeed and why they mostly hunt at night when they have the added cover of darkness.

The leopard we filmed - a 12 yr old female - used stealth in a remarkable way. She hunted in broad daylight on an open plain, using only a narrow gully as her cover. Her strategy was to walk along this 1km gully (basically a dry river bed) looking for impala grazing close to the edge. We only saw her succeed once but it was amazing to see her burst out of the gully, grab an impala in one fluid movement and drag it back into the gully. The whole attack lasted less than 6 seconds - pretty impressive given that the impala was probably 20-30 kilos heavier. You can count on one hand

BELOW: A fledgling sparrowhawk chases a jay in a woodland clearing in Autumn. Female sparrowhawks are much larger than the males, and can capture larger prey

PHOTO: ADRIAN SEYMOUR, JAVIER MESA

how many times a whole leopard hunt has been caught on film so this moment felt quite special.

Can you tell us about some of the strategies you had to deploy to film The Hunt?

Yes, we had to employ almost as many strategies as the animals we were filming! Traditional strategies, like hide filming were important but on The Hunt we pushed the boundaries on some of the other filming techniques, which really added to our editorial. For instance, we used the Cineflex - a long lens gyro stabilised camera system normally used on helicopters - on a whole range of ground transport so that we could track our subjects as they moved and hunted. This strategy allowed us to keep pace with wild dogs while they chased wildebeest, stalk with a leopard and a tiger, and follow hunting killer whales and polar bears. It's a perspective that really puts the audience at the heart of the action and in the drama of the moment. In India, we even came up with a design for mounting a Cineflex on a domestic elephant to film tigers. Tigers don't see elephants as a threat so using our 'Eleflex', as we called it, allowed us to follow the cats into areas that would have been impossible to take a vehicle.

Predator or prey, who did you find yourself rooting for when you were filming?

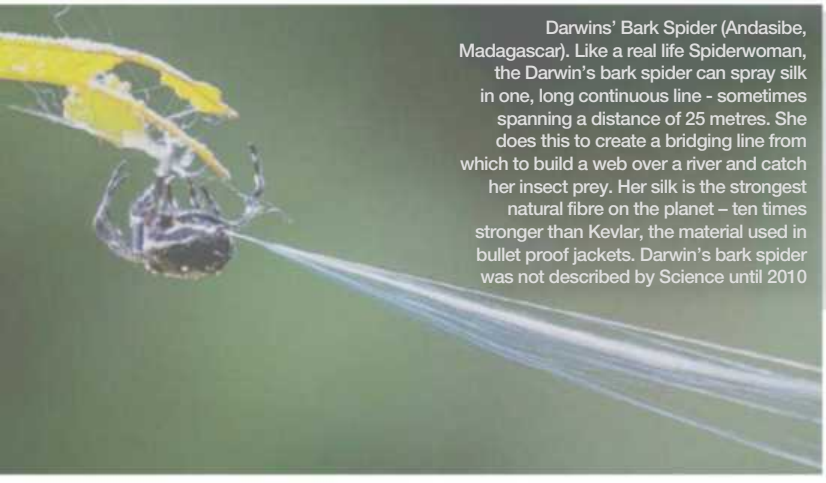
Good question, but it varied from sequence to sequence. It's difficult not to feel sympathy for a wildebeest being drowned by a crocodile or torn apart by wild dogs but, at the same time, you can't help admire the huge amount of effort that goes into each hunt. (Audiences needn't be concerned, our focus for the series is the strategy rather than the kill so viewers will be spared the gory scenes!)

You have to remember that survival is on the line for both hunted and the hunter. Indeed, the situation is arguable more acute than the predators who fail most of the time. Nile crocodiles, for instance, only succeed once in every ten strikes so by the time they do catch a drinking wildebeest you're rather rooting for them! In this series, we really want the audience to feel empathy for predators but I don't think it really matters whether you root for the hunter or hunted. The important thing for us as filmmakers is to generate enough emotion for the audience to engage with one or the other.

ABOVE: The harpy eagle of the South American jungle is a monkey-eating eagle, with talons as long as a grizzly bear's claws that must become the most powerful bird of prey on Earth in order to lift prey that weighs as much as itself

Each has something special, whether it's the intelligence of killer whales, the patience of Nile Crocodiles, the ingenuity of a Portia jumping spider, or the stamina of wild dogs

Male Parson's chameleon with insect prey - tropical forest, Andasibe , Madagascar. Chameleons catch their prey with their long sticky tongues. This tongue can shoot out at at 20 kmph. The tip is like a boxing glove which engulfs the prey - usually by the head



Darwins' Bark Spider (Andasibe, Madagascar). Like a real life Spiderwoman, the Darwin's bark spider can spray silk in one, long continuous line - sometimes spanning a distance of 25 metres. She does this to create a bridging line from which to build a web over a river and catch her insect prey. Her silk is the strongest natural fibre on the planet – ten times stronger than Kevlar, the material used in bullet proof jackets. Darwin's bark spider was not described by Science until 2010

The Hunt is as much about the habitats as the species themselves, which were the most challenging to film in?

Every habitat brings its own challenges. Filming in the Arctic in early Spring requires huge planning and a lot of resources. To film the polar bears' meltwater and aquatic hunts we had to hire an ice breaking ship for five weeks - not a cheap undertaking! At the other end of the temperature extremes are deserts - if you're trying to film hotrod ants in the Namib you have to deal with sand temperatures that often hit 70 degrees Celsius, while, at the same time, focusing on an animal only a few millimetres long. Then there's tropical forests, which are often regarded as the most challenging habitat - not just because of the humidity and the rain but because finding and getting close to animals can be extremely difficult and time consuming. And who could say the open ocean is any less challenging than jungles. Here every shoot is unpredictable. You can set off to film one species but, even with the best planning, whether you find it or not is often pot luck. Quite often you end up filming something different!

What was your favourite behind the scenes moment from The Hunt?

I can't boil it down to one moment as there were so many and you'll see the best of these in our making of films that accompany each episode. However, my favourite moments would include the following: cameraman Rolf Steinmann being chased by a polar bear and his comments about filming the meltwater hunts after the skidoo pulling all of his camera equipment sank to the bottom of the sea; the trials and tribulations of cameraman Mark Smith as he tries to film the world's smallest otter - the Chilean sea otter; the 'Eleflex' used to film tigers in India (basically a gyro stabilised Cineflex system designed to hang off the side of a huge elephant); and the excitement of filming a feeding blue whale - something that has never been done before.

BELOW: Gotham, a domesticated Asian elephant, with his handler, Mr. Jhaloo and cameraman Jamie McPherson, ready for another excursion into the forest to film tigers. Gotham sports a bespoke camera rig, "the eleflex", a stabilised camera that could be lowered to the floor. Tigers and elephants are used to each other in India's Bandhavgarh National Park, so the crew could use the eleflex to get close, low angle shots of tigers in the deep forest

Stories from The Hunt

Bengal Tigers stalking chital deer in the Indian forest

Jonnie Hughes, Producer

A tiger is the biggest forest predator on earth. Although we have filmed tigers hunting in the open in the past, 90% of their hunts take place in the forest and that's the habitat where they excel. It's not easy – the tiger has to find its prey in the first place; it's a real challenge to approach anything that's obstructed by trees; creeping up without being noticed is extremely difficult in a forest covered in dried leaves and twigs; and tigers are plagued the whole time by other animals doing alarm calls whenever they see one. Yet all of these things the tiger has cracked.

It's very rare for anyone to film a tiger hunting in the forest, and it's never been done with the landmark production values we aspire to. In India you're not allowed to follow a tiger in to the forest on a jeep, and even if you could, a tripod on the back of a jeep bounces up and down if anyone even sneezes.

So we put our camera on an elephant. Tigers are very familiar with elephants and vice versa – domesticated elephants have been used for generations in India. Being on an elephant means it smells of elephant so you don't smell. It's a cloaking device. And deer know that an elephant is not dangerous to them. They'll walk towards

PHOTO: HUW CORDEY, SCREEN GRAB, JONNIE HUGHES

elephants. The first day that we switched on the camera Jamie McPherson, our cameraman, was blown away because this little deer walked straight towards the lens. Deer would just not do that towards a normal camera.

But elephants bring their own problems - what we wanted to do for The Hunt was to create beautiful footage at a tiger's eye level. It was no good being 12 feet up on an elephant and looking down. Consequentially we fell upon the idea of using a stabilised camera on what would have to be a bespoke rig, which we could lower by a pulley from the top of the elephant down to the ground, and then manoeuvre up and down as much as we needed to look over the grass. And we could spy the tigers from that.

Then we tried it on a jeep as well and it turned out that in spite of what we initially thought, we were able to get some great shots from the road. What we discovered was that as you drive along the road system, with a gyro-stabilised camera rigged to the back of the car you can keep filming, in a long tracking shot. Tracking shots are the bread and butter of Hollywood now, from Bond to Bourne to Christopher Nolan's films. The camera never stops moving, and as a lot of hunts are a mobile event that technique is perfectly suited. It's great because it gives the viewer a sense of the environment the animal is in as well as focussing their attention on the animal itself. Essentially, you feel like you're there, and that is our goal.

ABOVE: The lion fish uses its flamboyant patterns and fins to disguise fine movements from its prey as it edges ever closer ready to strike

The Hunt becomes the hunted

Sophie Lanfear, Assistant Producer

In the Arctic we stay in hunters' cabins about four metres by four metres. There are four of you in there so it's cramped. In the summer months the chances of you seeing a polar bear are very, very slim. Then one day we came back from filming and someone had broken in to our cabin. It had pulled the door off its hinges, eaten all the chocolate, oil and butter and then gone through all the trash out back. He'd also worked his way through 20 kilos of new food stock we'd just got in, which meant no fresh food for us. Suddenly we were all a bit more nervous about that 500m walk to the toilet hut.

We cleaned everything up and fixed the door as best we could. Then, a few days later, we met our intruder, a polar bear, on the way back to the cabin. He didn't scare that easily, which was not a good sign. Sure enough, the next night the bear was pounding at the front door. We scared him off again, but the next time we went off to film we saw the bear heading straight towards the cabin and we filmed him breaking in again. This time he just destroyed the place. The only thing he didn't eat was the Marmite. And then every five hours basically he'd come back. We couldn't leave the hut: we had to get a guide with bootfuls of explosives to make lots of loud noises and to re-stake it as our territory. The bear didn't come back after that. Hunting strategies? Well, we do know that bears don't like Marmite. At least this one didn't.

Humpback whale and killer whales, (also called orca). Each year thousands of humpback whales migrate up the west coast of Australia on their way to its northerly point to give birth. Some humpbacks have their calves on the journey. The calves are targeted by killer whales but they must get past the mother first. This is no mean feat as she is armed with a powerful 5 metre wide tail and long barnacle covered flippers. Sometimes she is helped by male humpback escorts. But even with these escorts they are not always a match for the teamwork and intelligence of the killer whales

Army Ants in Ecuador

Jonnie Hughes, Producer

Army Ants are the ultimate player of the game of hide and seek in the forest in that they can turn over every leaf. We were with an army ant colony of approximately one million individuals (they can reach up to 2 million) and it was remarkable watching them work.

We used a new piece of kit, a mini camera called a Flare that's the size of an iPhone. We mounted lenses that are used for microscopes on it and we hung it off a very small boom arm, with a little handheld pan-tilt head on the end of it with a joystick we could move up and down. We could therefore fly this camera like a miniature helicopter over the army ants. Again, we were trying to get that tracking, dynamic feel that runs right through The Hunt, but rather than huge Bengal tigers here it was with army ants - which are a centimetre long.

It still needed five of us to work this little camera. You use the jib arm to fly over the top of the ants but you're panning at the same time to get tracking shots. So we had one of us manning the pan and the tilt, one of us doing the jib arm, one of us pulling focus – which is actually the hardest job because when you've got a camera that small the depth of field is absolutely tiny so you can have one ant in focus and the one behind it won't be – and then we had two people on lights. And we needed those lights - the problem with the forest floor is when you're looking at a tiny pool of interest you have to put a lot of light in to it to get a decent shot.

So all five of us are standing in the forest with our rig. We knew that there'd been an ant bivouac – they sleep in a large ball - 20 metres in front of us and we knew it was heading this way so we ran ahead, set up the mini camera and we waited. It was only when I saw the swarm that I thought, 'What do we do when the swarm hits us?' We'd been told to stand still – army ants are nearly blind and can only sense movement. We all had wellies on and we'd sealed them at the top with Sellotape. That, we were assured, is enough to stop the ants from getting up in to your trousers and biting you.

When it comes, the raid front is seven or eight metres across which is as far as you can see in a forest. It looks like this ocean of ants is coming towards you. We filmed as much as we could as they were coming through and then we just had to stand there and wait for them to go by. You look down and surrounding everything you can see is an ant. Just in front of the raid all of the animals that have been hiding under leaves that you haven't noticed are trying to get out of there. So as the ants crawl through all these scorpions and spiders, huge millipedes, butterflies and grasshoppers are evacuating. Some of those things are quite nasty. The Brazilian wandering spider is like a nightmare – it's big, its bite could put you in hospital and it jumps across the forest floor in order to get away from the ants. We saw lots of those running away. Everything runs away from an army ant swarm, even jaguars – it turns out that the ultimate predator is the one that works as a team.

ABOVE: The South American army ant lives in colonies of up to 2 million individuals. The colony swarms by day, and sets up camp each night in a tree by creating a nest out of the living worker ants

BELOW: An army ant raid discovers a katydid hiding in the leaf litter. Within seconds the ants overcome it. Within minutes they have butchered it, and carry it back to their base

PHOTO: SCREEN GRAB, JASON ROBERTS, JAMIE MCPHERSON

Polar Bears hunting seals on sea ice in the Norwegian archipelago of Svalbard

Jonnie Hughes, Producer

Svalbard in June and July is an astonishing place. At that time of year it's half ocean and half ice. A lot of the sea ice remains; in sheltered areas some of it is completely intact, but in the inlets and the fjords it has broken in to drift ice, and out in the open ocean it can have vanished completely by that stage.

That makes for various habitats to which polar bears are trying to adjust – the nature of the hunt, once again, is dependent on the nature of the environment.

Our plan was to try and film two types of ice stalking. One was in an area where the ice was intact but had holes in it. Another was where there was drift ice, ice floating around like a constantly shifting maze.

The stalk we filmed on the more solid ice is called a meltwater stalk and though we'd read about it we'd never seen pictures or filmed it. The bear will see a seal and because it can't approach the seal - the ice is too wobbly - it drops down in to holes in the ice. Then it will keep popping up through other holes nearer and nearer to the seal. Right by the seal there will be a hole – because that's the seal's escape route. Eventually the bear pops up through that hole and surprises the seal. Or that's the idea.

BELOW: Polar guide Håvard Festø, producer Jonnie Hughes and cameraman Jamie McPherson capture the scene as the sea ice melts at the start of summer

Alastair Fothergill, executive producer of The Hunt, sits beside a colony of black-browed albatross on Steeple Jason Island in the Falklands

In order to film this behaviour we got on snowmobiles and drove out over this really quite shifty ice. Lo and behold, we managed to find a bear stalking a seal – our cameraman Rolf Steinmann filmed it dropping in to the water and then bobbing its head up through these ice holes. Eventually it bumped in to the ice and the seal noticed it and it scarpered. It wasn't a successful hunt – but then that's part of the story. It gets harder at this time of year and only one in five of this kind of stalk is successful.

What was interesting was that after that, the polar bear looked around and saw Rolf and his team sitting on the ice, and then it started doing the same stalk towards them. Because polar bears are not scared of anything: they don't need to be. They also think of anything as edible. Some of the best close-up shots we got are from when the bear was stalking Rolf! Of course, the bear could have leapt out of any of the holes around the crew, so after a while they decided it was getting too close and got back on the snowmobile.

The other type of stalk we did was the drift ice one. Here only one in 20 hunts is successful – they try and fail a lot. We had an icebreaking ship so we could go in to the drift ice, anchor there, drop the little boats down and then cameraman Jamie McPherson and I could navigate our way around the drift ice looking for bears. We followed this really skinny one for a few days. It's a hell of task – they've got to spot a seal on the ice before a seal spots them, use the ice to hide as they swim around and constantly check where the seal is – because the ice is always shifting. In the end we found one that came over the top perfectly in to the shot. We framed up on the only seal that was around, guessing it would go for that. Then we lost the bear. We didn't know where it was – which I guess is the point. Then this bear just emerged behind the seal, chased it in to the water and caught it. It was astonishing, and it has never been filmed before. ■

Watch THE HUNT

The Hunt is a landmark series that explores the dynamic relationship between predators and their prey. From open grasslands to dense forests, the arctic to the open ocean, the series will reveal the challenges predators and prey face in these very different worlds.

The Hunt will also feature animals that have rarely been filmed, including the endangered South American marine otters.

Exclusive Asia Premiere *on BBC Earth*

Monday, 2nd November at 7.05pm(JKT/BKK), 8.05pm(SG)

Singapore: StarHub TV Channel 407

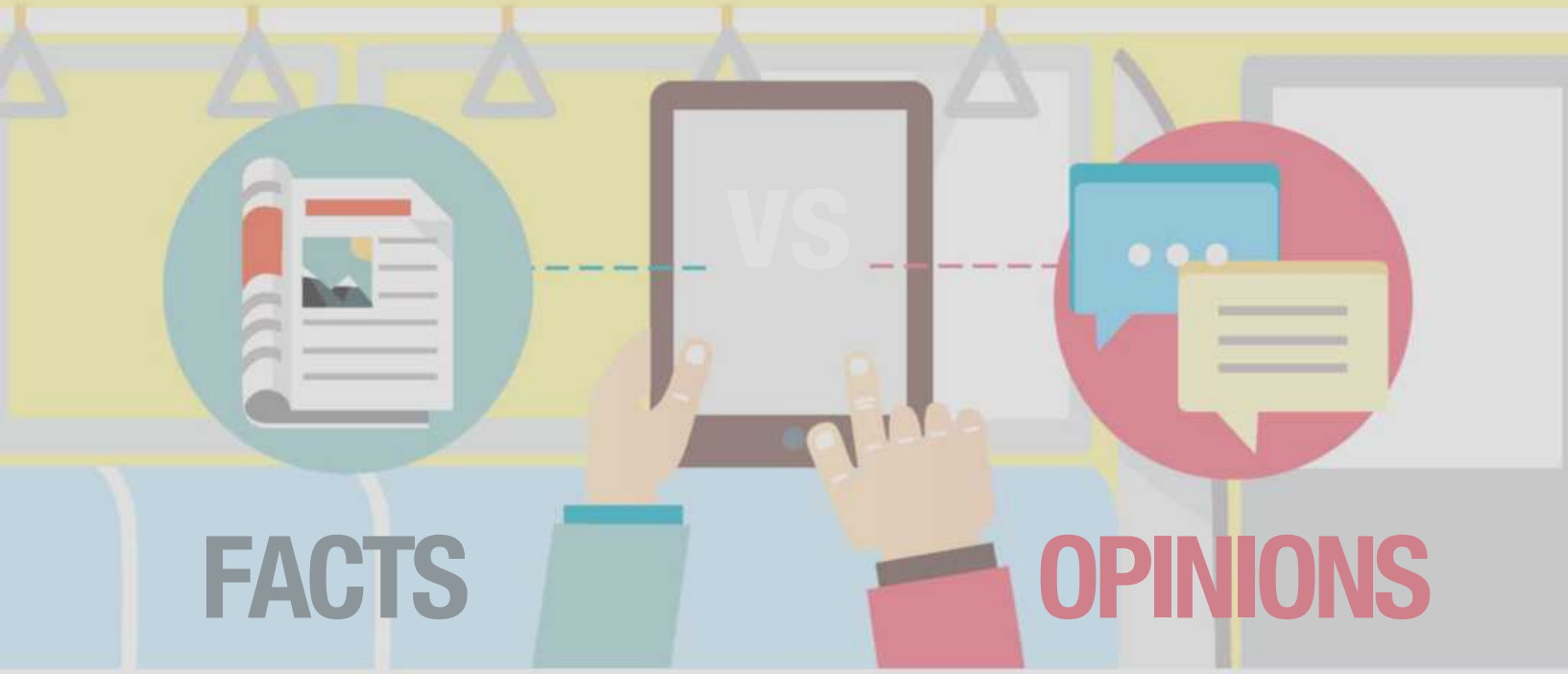
Malaysia: Hypp TV Channel 501

Indonesia: Indovision Channel 200

Thailand: Truevisions Channel 568

Hong Kong: nowTV Channel 220 and Hong Kong Cable TV Channel 49

For other countries and more details, please visit **www.bbcasia.com**



"The fewer the facts, the stronger the opinion." – Arnold H. Glasgow

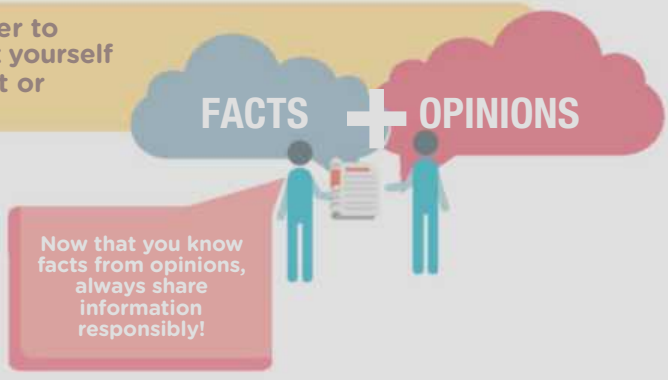
When there are few facts cited in an article, the contents of the article will consist merely of the writer's personal opinion.

Whether an article is supported by facts affect its credibility. An article backed up with factual evidences make the article more credible. While an article based on the views, beliefs and preferences of the writer may be bias and thus, less credible.

Therefore, when researching for information, look for articles that are supported with facts and evidence. This will ensure that the information you seek is more truthful and trustworthy.

Sometimes, facts and opinions are used together to persuade readers into agreeing with a point. Ask yourself these questions to check if a statement is a fact or an opinion:

- Can the statement be proven by evidences?
- Are the evidences from reliable sources?
- Where are the sources from? Are they credible?



Source
Look at its origins. Is it trustworthy?

Understand
Know what you're reading. Search for clarity.

research
Dig deeper. Go beyond the initial source.

evaluate
Find the balance. Exercise fair judgement.

Knowing how to distinguish between facts and opinions helps us to discern the information surrounding us. Here's how to tell facts from opinions:

FACTS

Facts are statements that can be proven to be true or false. They are backed up by evidence.

Eg: Dhoby Ghaut MRT Station is one of the deepest stations, with its deepest point at 28 metres below ground level.

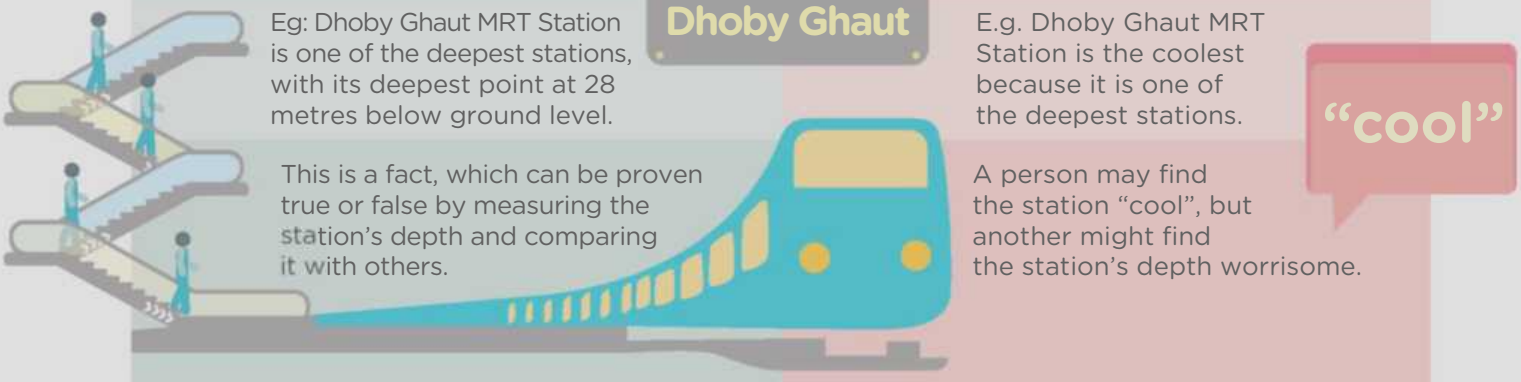
This is a fact, which can be proven true or false by measuring the station's depth and comparing it with others.

OPINIONS

Opinions are expressions based on personal beliefs or views.

E.g. Dhoby Ghaut MRT Station is the coolest because it is one of the deepest stations.

A person may find the station "cool", but another might find the station's depth worrisome.



A fact can only have one true statement. It can be found in:

- Research studies
- News reports
- Encyclopaedias

An opinion can consist of many personal views. It can be found in:

- Letters to editors (newspapers)
- Facebook comments
- Argumentative papers

References:

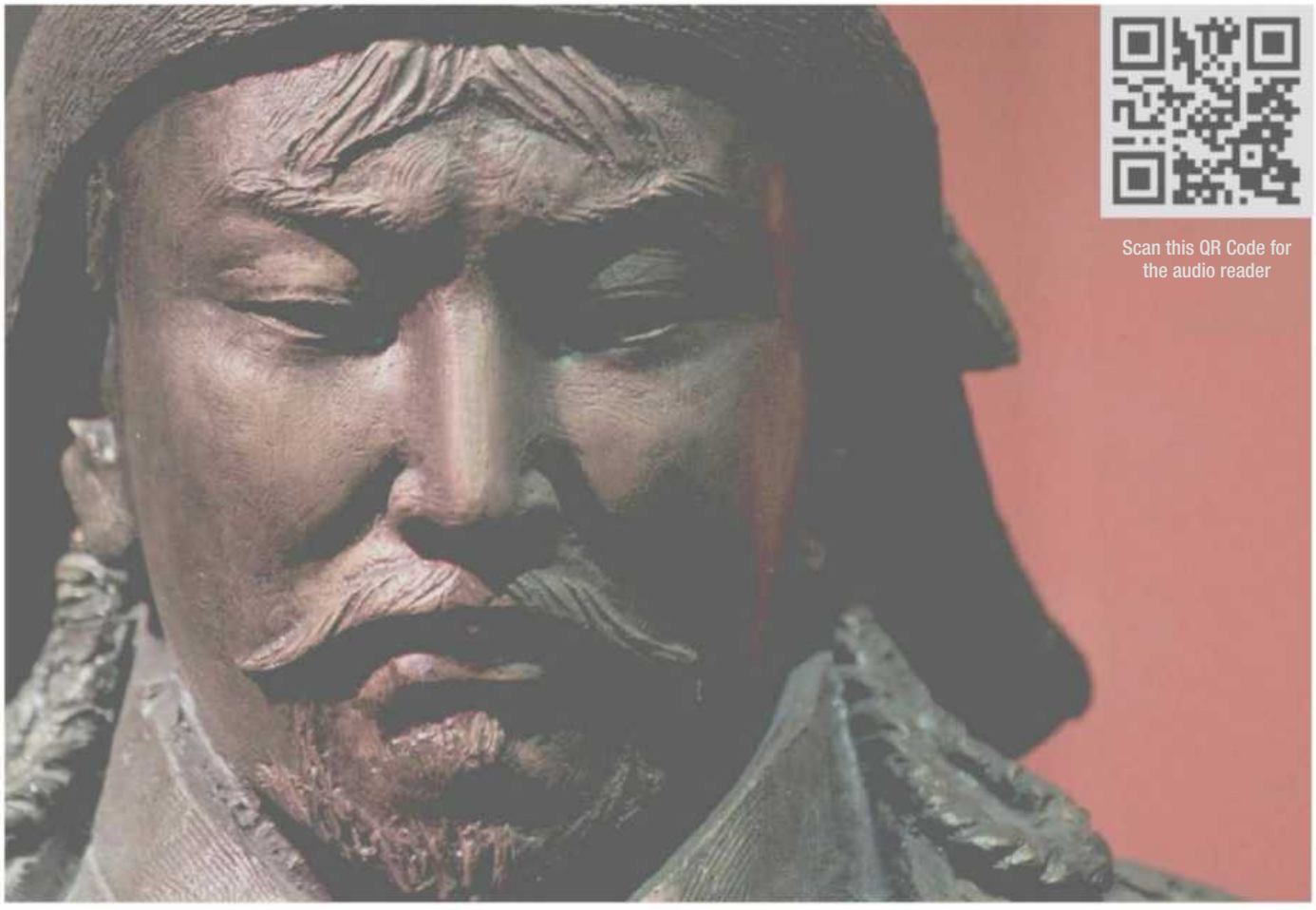
- Education (2011). 'Distinguishing between fact and opinion help'. **Retrieved from http://www.education.com/study-help/article/difference-fact-opinion/ on 8 April 2014.**
- BBC Skillwise (2011). 'What are facts and opinions?' Retrieved from **http://www.bbc.co.uk/skillswise/factsheet/en06opin-l1-f-what-is-fact-and-opinion on 8 April 2014.**
- Borough of Manhattan Community College (2014). 'Knowing the difference between facts and opinions'. **Retrieved from http://www.bmcc.cuny.edu/lrc/studyskills/factsandopinions.pdf on 8 April 2014.**

fb.com/sgsure
nlb.gov.sg/sure

NLB | National Library Board Singapore

S.U.R.E.

To read more on S.U.R.E. infographics, please visit **nlb.gov.sg/sure/infographics**



Scan this QR Code for the audio reader

A statue of Genghis Khan on display at Chicago's Field Museum in 2013. In one of the most astonishing achievements in history, this leader of a band of 2 million illiterate nomads established an empire that would ultimately cover most of the known world

GETTY

THE BRUTAL BRILLIANCE OF GENGHIS KHAN

Yes, he was a ruthless killer, but the Mongol leader was also one of the most gifted military innovators of any age

By Frank McLynn

Genghis Khan was the greatest conqueror the world has ever known. He is a legendary figure, perhaps second in fame only to Julius Caesar, and in popular imagery is the very avatar of savagery and barbarism. And what could be more damning for the modern

reactionary politician than to be accused of being to the 'right of Genghis Khan'? The real Genghis, however, was a genuine phenomenon. He and his sons vanquished peoples from the Adriatic to the Pacific, reaching modern Austria, Finland, Croatia, Hungary, Poland, Vietnam, Burma, Japan and Indonesia. The Mongol empire covered 12 million contiguous square miles – an area as large as Africa. In contrast, the Roman empire was about half the size of the continental USA. By 1240, Mongol conquests covered most of the known world – since the Americas and Australasia were unknown to the 'world island' of Europe, Asia and Africa. Modern countries that formed part of the Mongol empire at its greatest extent contain 3 billion of the world's 7 billion population.

Genghis (1162–1227) and his sons waged major wars on two fronts simultaneously and conquered Russia in winter – both feats that eluded Napoleon and Hitler. How was this possible for a land of 2 million illiterate nomads? The answer was a quantum leap in military technology, which brought mounted archery to its acme. The speed and mobility of Mongol archers, the accuracy of their long-range shooting, their uncanny horsemanship – all allied to Genghis's ruthless 'surrender or die' policy and his brilliant perception that this gave him the possibility of living off tribute from the rest of the world – combined to make the Mongols unbeatable. As the military historian Basil Liddell Hart pointed out, Genghis was a military innovator in two important respects: he realised that cavalry did not need to have infantry backup, and he grasped the importance of massed artillery barrages.

Most historians claim that this astonishing achievement was the result of massacre and bloodshed not seen again until the 20th century. It is the task of the honest historian to attempt a balanced, judicious estimate of this conventional appraisal, all the more so since modern revisionism has seen something of an 'overswing' of the critical pendulum. One school of thought would make the Mongols culpable for every military atrocity that has ever occurred; the opposing one would make them harbingers of world peace and security, beset by a few regrettable excesses.

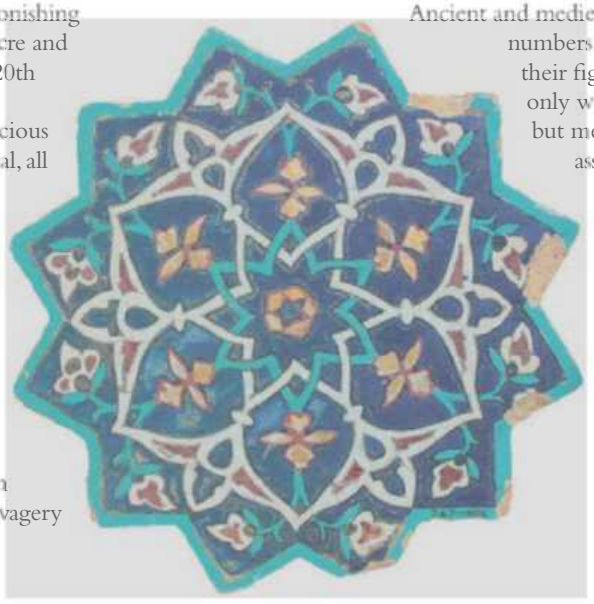
Military historian Sir John Keegan made Genghis responsible for the savagery of the Spanish Reconquista against the Moors in the late 15th century and their massacre of the Aztecs and Incas. The Mongols are supposed to have imported ruthless ferocity to Islam, which in turn transmitted it to the crusaders, thence back to Spain and, after Columbus's voyages of discovery, the New World: "The awful fate of the Incas and Aztecs… ultimately washed back to Genghis Khan himself." The Harvard historian Donald Ostrowski replied, correctly, that "ruthless ferocity" was actually introduced to Islam by the crusaders.

In contrast to the 'Genghis as monster' take on events, the anthropologist Jack Weatherford, in his 2004 hagiography of Genghis, soft-pedalled the casualties caused by the Mongols and stressed instead their enlightened attitude to women, their avoidance (mostly) of torture, their transmission of culture and the arts, and even their (alleged) role as fount and origin of the Renaissance.

These divergent modern views are a projection across the centuries of diametrically opposed views of the Mongols entertained in the 13th century. For the English chronicler Matthew Paris, the Mongols were Gog and Magog aroused from their slumber; they were the demons of Tartarus, the myrmidons of Satan himself. For the great Franciscan thinker Roger Bacon, the Mongols represented the triumph of science and philosophy over ignorance.

Since one version of Genghis Khan is that of a cruel despot who raised mountains of human skulls, we should first ask: how many died as a result of his wars and conquests? The answer can only be guesswork, however sophisticated, for three main reasons. Ancient and medieval chroniclers routinely multiplied numbers, sometimes 10-fold, so we have to discount their figures. Estimates of fatalities can be made only when we have accurate population statistics, but medieval census figures are unreliable. And the assessment of war casualties is a notorious minefield, even in the modern age (scholars cannot agree on the figures for deaths in the Second World War).

There were three great Mongol campaigns between 1206 (when the local warlord Temujin was acclaimed as Genghis Khan, emperor of Mongolia) and 1242 when the Mongols withdrew from Europe following the death of Ogodei,



A star-shaped tile made in Iran in c1444. By then, thanks to Mongol expansion, many motifs common to Chinese art were being seen in western Asia

V&A IMAGES

"There are no signs in Genghis of a mindless or psychopathic cruelty; everything was done for a purpose. He exceeded in degree but not in kind the other killers of the age"

Genghis's son and successor as Great Khan. The European conquest of 1237–42 probably accounted for a million deaths while the subjugation of modern Iran and Afghanistan from 1219–22 cost 2.5 million lives.

The real problem of historical interpretation comes in the great campaign to conquer the Jin regime of northern China, which lasted from 1211–34. We can have only the haziest idea of the population of northern China at the time, but it was probably somewhere in the 60–90 million mark. Medieval and early modern demography of China is an inexact science, to put it mildly. A distinguished Sinologist has concluded that, depending on which model you use, the population of China in 1600 could have been 66 million, 150 million or 230 million. What is clear is that sustained warfare in China always generates massive casualties.

Two obvious analogies for Genghis's 23-year war against the Jin are the An-Lushan revolt against the Tang dynasty in 755–63 and the great Taiping rebellion of 1850–64. The An-Lushan convulsion caused 26 million deaths and the Taiping 30 million. We should also note that 27 million were killed in the Sino-Japanese conflict of 1937–45. Using these statistics as a lodestone, scholars argue that the likely fatalities from 1211–34 were 30 million. If we then include casualties in the 'little wars' Genghis and his sons waged against people like the Tanguts, the Bulgars, the Armenians and the Georgians, we arrive at a total of some 35–37 million deaths attributable to the Mongols.

A Chinese soldier bends over the body of a dead comrade in c1937. Like the Sino-Japanese conflict of 1937–45, Genghis Khan's campaigns in China would have caused a huge death toll

GETTY

Why was the death toll so high, and why were the Mongols so ferocious? Different reasons have been adduced: the Mongols spread terror and cruelty because they had a small-scale steppe mentality transposed onto a global stage; because, in terms of the Mongols' divine mission to conquer the world for their supreme god Tengeri, resistance was blasphemy; because they feared and hated walled cities and expended their fury on them once taken; because it was the most efficient way to warn already conquered peoples not to attempt 'stab in the back' revolts as the Mongols pressed ever forwards.

The simplest explanation for the chilling policy of 'surrender or die' was that the Mongols, as a far from numerous people totalling at most 2 million souls, were obsessed with casualties. For them, the best-case scenario was a walkover surrender in which none of their troops died. This explains why nearly all the cities that surrendered without even token resistance received relatively good treatment.

There are no signs in Genghis of a mindless or psychopathic cruelty; everything was done for a purpose. It is important not to judge him by 21st-century standards but to see him in the context of general behaviour in the 13th century. He exceeded in degree but not in kind the other killers of the age. One could give any number of other instances: from the slaughter of the southern Chinese (Song) by the Jin in Tsao-Chia in 1128, through the massacre of the Albigensians by fellow Christians at Béziers and Carcassonne in 1209, to the killing of 30,000 Hindus at Chitor in 1303 by the troops of Ala-ad-din Khilji.

It is wisest to accept the judgment of a notable historian of medieval Russia, Charles J Halperin: "(Genghis) was no more cruel, and no less, than empire builders before and since. Moral judgments are of little help in understanding his importance." Moreover, it is only fair to point out that great wartime leaders, whether Lincoln during the American Civil War or Churchill and Roosevelt in the Second World War, sent hundreds of thousands to their death for causes that a Martian observer might not necessarily see as noble. Julius Caesar is supposed to have caused a million deaths during his 10-year conquest of Gaul, but the Caesar that predominates in the public consciousness is the statesman, military genius and superb writer of prose, not the butcher. In the 21st century we may take a dim view of Genghis's projects and ambitions but we should remember, as Plato pointed out long ago in the Protagoras, that even the Hitlers, Stalins and Maos do not consider themselves evil, but rather driven by some quasi-divine mission (the Reich, the classless society, the New Man).

The pro-Genghis camp asserts that it was as a result of his activities that China was brought into contact with the Islamic world and thus with the west, since the west had already made its presence felt in the Muslim world during the crusades. Trade, the Mongol courier or 'pony express' system, and Genghis's law code, the yasa, were the main pillars of the Mongol peace (Pax Mongolica), a period sparked by the stabilising effects of the Mongol empire.

Genghis Khan captures a Chinese town in this scene from the 16th-century Persian History of Genghis Khan. The Mongols notoriously employed a 'surrender or die' policy, possibly because they were obsessed with avoiding casualties among their own fighters

BRIDGEMAN

"The Mongol empire served as a transmission belt for technology, science and culture. The Mongols' conquests were a rivet that held the 'World system' together"

Marco Polo is shown travelling by camel caravan with his family in the 14th-century Catalan Atlas

After 1220 the Mongol propensity for trade rather than war gradually increased, particularly when Genghis himself was won over to the idea that agriculture generated more wealth than nomadism. It was said that you could travel from Palestine to Mongolia with a gold plate on your head and not be molested, but the journey was still an arduous one because of primitive transport. Even in the halcyon days of the Pax Mongolica, it took a traveller 295 days to get from Turkey to Beijing. Yet the Mongols undoubtedly opened up the world.

Until 1250 there was in the west a narrow European viewpoint that saw the world virtually end at Jerusalem. The journeys of the Franciscans Carpini and Rubruck, and the more famous one of Marco Polo (and that of the Chinese traveller Rabban Bar Sauma in the opposite direction), cleared the way for new vistas. Learned people finally got a sense of the size of the world and its population. The globe shrank as Venetian traders appeared in Beijing, Mongolian envoys in Bordeaux and Northampton, and Genoese consuls in Tabriz. There were Arab tax officials in China, Mongolian lawyers in Egypt, French craftsmen in the Mongol capital of Karakorum. The art of Iran was influenced by Uighur and Chinese motifs.

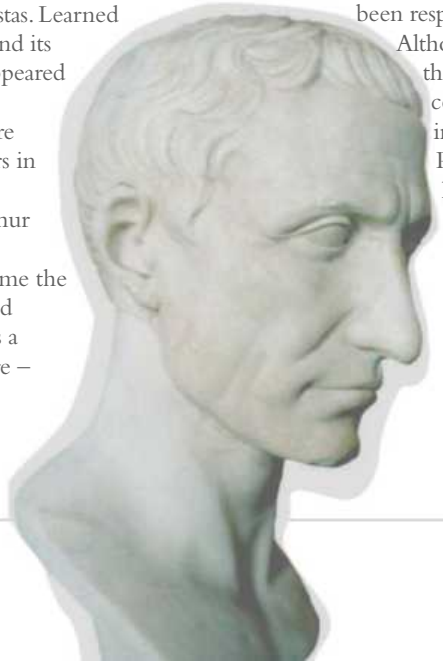
From China to the Islamic world and Europe came the knowledge of firearms, silk cultivation, ceramics and woodblock printing. The Mongol empire served as a transmission belt for technology, science and culture – particularly, but not solely, between China and Iran. In short, the Mongol conquests were a rivet that held the 'world system' together. The southern route of the Silk Road, which had fallen into disuse in favour of the northern and middle routes, was revived and linked the Aral and Caspian Seas with Byzantium. Some writers even trace a causal line from the Pax Mongolica to the discovery of the New World by Columbus, the age of European exploration and expansion and the Renaissance itself.

There is a good deal of truth in all of this, but anti-Mongolists have made some forceful rebuttals. Some historians claim that the alleged era of peace and tranquillity ushered in by the Pax Mongolica has been overdone, that pro-Mongolists have concentrated on the untypical 20-year period from 1242 when the great peace was a reality, and have ignored its collapse when Genghis's empire shivered into four fragments. Others claim that the 'world system' view is overstated, since the intercourse between east and west was largely one-way traffic, with no real Chinese equivalents of Rubruck, Carpini or Marco Polo. They also contend that the importance of journeys across Asia from the west has been exaggerated, and that they cannot be compared with the achievements of the Age of Discovery.

A refinement of this view is that a true 'world system' is possible only if maritime trade is brought into the picture, but the Mongols feared the sea (rightly, as it turned out, from their later abortive invasion of Japan) and preferred a gruelling journey overland of possibly 18 months to the terrors of the ocean, with the Indian Ocean being the main obstacle.

Finally, there are those who say that, even if we concede the reality of a 'world system', its unintended consequences were largely baneful, since the Mongol empire served as a vector for devastating disease. Rinderpest or steppe murrain, a disease in ungulate animals similar to measles in humans, devastated cattle herds in Eurasia from the 1240s on, spread by the Mongols' conquests in Russia and eastern Europe from 1236–42. Even worse, the Mongols may have been responsible for the spread of the Black Death. Although there are many conflicting views on the origin of this pandemic, it seems clear that central Asia was a major vector of the disease, in particular the new avenues of the Silk Route opened up by the Mongols, which had their terminus at the Crimea.

There are two final counts in the anti-Mongol indictment. One is that,



A bust of Julius Caesar, who may have caused a million deaths during his conquest of Gaul. Unlike Genghis Khan, however, he is remembered as a brilliant statesman and superb writer of prose

TOPFOTO/BRIDGEMAN

"The Mongols' system was always inherently unstable, since they neither traded nor produced, but lived by extracting a surplus from the conquered and so depended entirely on the toil of the vanquished"

Genghis Khan with three of his sons in a c1305 Iranian manuscript. While the Mongols were the Europeans' match on the battlefield, they never produced a Thomas Aquinas or Anthony of Padua or the amazing cathedrals that sprang up from York to Reims

although the Mongols were phenomenal warriors and outstanding conquerors, their system was always inherently unstable, since they neither traded nor produced, lived by extracting a surplus from the conquered and so depended entirely on the toil of the vanquished. And since more and more Mongol princelings arose with 'entitlement' to privilege, this meant a never-ending cycle of conquest, subjugation and exploitation. Like the shark or Lewis Carroll's Red Queen, the Mongols could not stand still and had to move constantly forward. Even if they had reached the Atlantic – and but for the death of Great Khan Ogodei (Genghis's son) in 1241, they almost certainly would have done – sooner or later the bubble would have burst, and the subsequent contraction would have been exponential.

More seriously perhaps, the Mongols were a culturally unbalanced people. They had achieved a quantum leap in military technology, putting them far ahead of western Europe, but the Europeans were meanwhile producing Robert Bacon, Anthony of Padua, Thomas Aquinas and St Louis. Although the Europeans could match the Mongols in slaughterous behaviour (especially the atrocities visited on the Albigensians), they were at least producing the Divine Comedy, the Carmina Burana, the Roman de la Rose and the amazing series of cathedrals, either completed or begun in the 13th century, at Chartres, Amiens, Reims, Beauvais, Toledo, Burgos, Cologne, York and Lichfield.

Genghis Khan, an illiterate nomad, was a genius at many levels, not least in that his achievements, as it were, came from nowhere. All other great conquerors were literate and had a huge background of tradition and knowledge to draw on – Alexander the Great from Aristotle, Julius Caesar from the whole canon of ancient Greece, Napoleon from the Enlightenment and the Romantic movement. Yet when Genghis is weighed in the balance against his contemporary Francis of Assisi, he is bound to seem a moral pygmy. Interestingly, it was Francis's followers who first made contact with the Mongols and brought back an amazing story that will endure as long as mankind itself: the career of Genghis Khan. ■

FRANK MCLYNN is a historian and author whose books include critically acclaimed biographies of Napoleon and Richard the Lionheart

BRIDGEMAN

QUANTUM PHYSICS IN 10 MINUTES

Even Nobel Prize-winning physicists are baffled by this tricky subject. But John Gribbin is here to reveal why quantum physics is relevant to all our lives

What is quantum physics for?

Quantum physics may seem like a pretty esoteric topic with no everyday practical value, but that's far from being the case. Quantum physics is the science you need to understand the behaviour of atoms, electrons and light. It therefore underpins the workings of microchips and lasers, among other things. The chemical bonds that hold strands of DNA together, and which enable the double-stranded molecules of the famous helix to unzip and make copies of themselves, operate purely in accordance with the laws of quantum physics. Quantum physics is the science of life: it doesn't get much more basic than that!

Wave, particle or both?

The understanding of physics that scientists had reached by the end of the 19th Century is now called 'classical physics'. It describes the behaviour of the material world in terms of the laws discovered by Isaac Newton, and it describes the behaviour of light and other electromagnetic radiation (everything from radio waves to gamma rays) in terms of the wave equations of James Clerk Maxwell.

Crucially, in the world of classical physics, waves are waves and particles are particles. They interact with one another – as when an electrically charged, jiggling electron emits radio waves – but they always retain their identity. Even the General Theory of Relativity (like its simpler cousin the Special Theory of Relativity) counts as a classical theory, because it retains this distinction between waves and particles, and preserves the idea that changes happen in a continuous fashion.

When Max Planck suggested that light was made up of particles, he completely overturned classical physics

Quantum physics overturns all of that. The first clue that something other than classical physics was needed came when Max Planck found that he could only explain some aspects of the behaviour of light (such as the nature of so-called black body radiation – see 'Jargon Buster') by treating light as being made up of particles, not a continuous wave. But other experiments still showed light behaving as a wave! Then it was discovered that electrons, which classical physics said were particles, behaved in some circumstances as if they were waves. Wave-particle duality, as it became known, lies at the heart of quantum physics.

Does quantum theory rule?

Wave-particle duality is not the whole story of the split between classical physics and quantum physics. In the world of classical physics, a particle such as an electron has a definite position in space, and is moving in a definite direction.

As long as you make allowance for all the forces it encounters along the way, you can calculate everything that will ever happen to it. This applies to all particles. The classical world is said to be 'deterministic' because once

PHOTO: GETTY, SCIENCE PHOTO LIBRARY

Scan this QR Code for the audio reader

What is this ?

These are particle tracks showing lots of electron-positron pairs. An electron is negatively charged and its positively charged antimatter particle is the positron. The electrons and positrons form these paired spirals as they swirl away from each other in a magnetic field. The area shown in this image is about two metres in height.

TIMELINE

1900

German physicist Max Planck (1858-1947) discovers that black body radiation can be explained if light is emitted in packets of energy, now called photons. This conflicts with the accepted idea that light is a wave.

1905

German physicist Albert Einstein (1879-1955) explains the photoelectric effect, in which light falling on a metal surface makes photoelectrons jump out of the surface.

1913

Danish physicist Niels Bohr (1885-1962) explains the spectrum of light radiated by atoms in terms of electrons jumping between fixed energy levels, like steps on a staircase, inside the atom. This is the 'quantum leap'.

1927

US physicist Clinton Davisson and UK physicist George Paget Thomson (pictured) share a Nobel prize for independently discovering that electrons can be diffracted like waves, confirming the reality of wave-particle duality.

1932

While studying cosmic ray tracks, US physicist Carl Anderson (1905-1991), sees the trace of a particle like an electron but with a positive charge. It is the positron, an antiparticle.

1985

David Deutsch (1953-) publishes a paper pointing out the possibility of making a true quantum computer. He predicts that they will carry out certain tasks much faster than a conventional computer can.

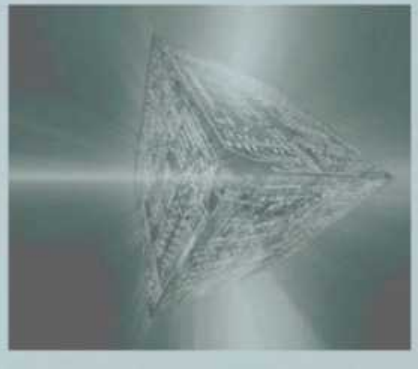


PHOTO: SCIENCE & SOCIETY, GETTY X2, SCIENCE PHOTO LIBRARY X2, NASA AMES/NICK BONIFAS

you know where everything is and where it is going, you can work out the entire future and the entire past. Both are determined by the way things are now, which doesn't leave very much room for free will! This is sometimes called 'Newton's Clockwork Universe'.

But according to quantum physics, an electron is never located at a precise place (because of its wave nature), and it is never sure where it is going. This is the 'uncertainty principle' discovered by Werner Heisenberg, who found there is a trade-off. Quantum objects can either have a relatively well-defined position and a poorly defined direction, or a well-defined direction and a poorly defined position. But they can't have both. It's the price of free will.

This ties in with another key quantum physics idea – probability. You can never say precisely where a quantum entity is or where it is going, but you can use the rules of quantum physics to work out probabilities, such as the probability that an electron will follow a certain trajectory, or the probability that a sample of radioactive material will decay and spit out a particle within a certain time.

What is a quantum?

A quantum is the smallest amount of something that it is possible to have. The smallest amount of light you can have, for example, is a particle called a photon. If you have a bright light, there are many photons streaming outwards. But as you turn the light down, there are fewer and fewer photons. Eventually, there are so few photons that they can be detected one at a time. Astronomers see this happening when they build up images of very faint objects using long exposures of charge-coupled devices (CCDs). When atoms emit light, they do so by rearranging their electrons to radiate energy. Like a ball bouncing down a staircase, the electron jumps from one energy level to another inside the atom, and a photon is emitted. This jump is known as a quantum leap.

A quantum leap is the smallest change it is possible to make – something to remember next time you see the term used in advertising.

Can we see quantum effects?

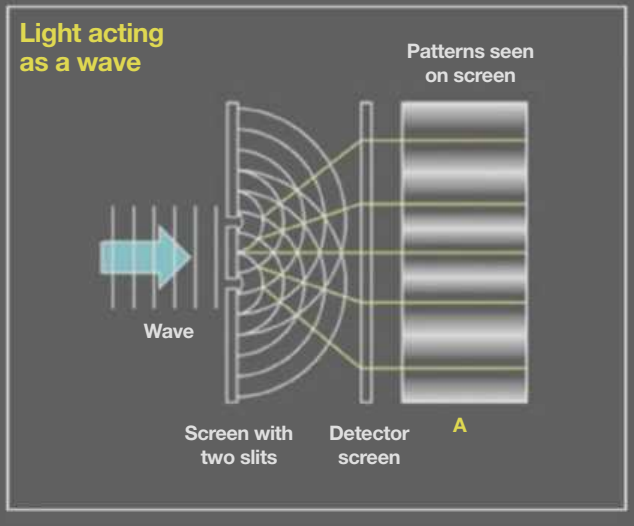
The definitive demonstration of quantum effects at work was carried out by a Japanese team in the 1980s. They took the classical experiment which 'proves' light is a wave and adapted it to electrons.

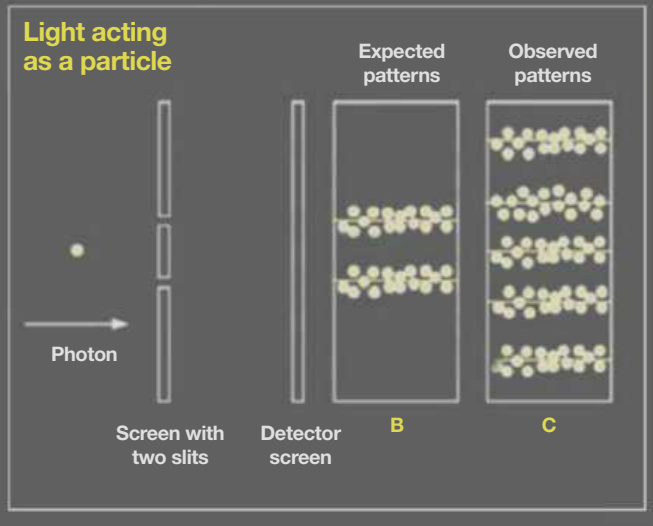
The traditional experiment involves sending a beam of light through two slits in a cardboard screen to make a pattern on another screen on the far side. Like ripples on a pond, the waves started to spread out from the two slits and interfered with one another to make the distinctive pattern. In their variation on the theme, the Japanese team fired electrons, one

D-Wave

Could this be the first quantum computer? Manufacturers D-Wave claim that it is, but have not revealed details of how it works. What we do know is that it's cooled to temperatures approaching absolute zero. The aim is to develop computers based on the superposition idea of quantum physics. These quantum computers will make classical computers look as primitive as an abacus.

THE KEY EXPERIMENT





In the 18th Century, debate raged as to whether light was a wave or a particle. But in 1803, English scientist Thomas Young showed that, when light is passed through two slits onto a backboard, an interference pattern appears. This is similar to what's seen when two sets of similarly generated waves collide in water (fig A). Light, he deduced, must be a wave. In the early 20th Century, however, Einstein and others demonstrated that light can also be seen as a stream of particles, called photons.

This is where things get tricky. When individual particles are sent one at a time through a double slit, as in Young's experiment, they should 'pile up' in two bands (fig B). Photons don't, though: even if you send photons through the double slit individually, an interference pattern is observed (fig C). Just to complicate matters, if you monitor which slit each photon is going through, the interference patterns are replaced by two bands.

The same applies to other fundamental particles, such as electrons. If that sounds a bit mind-blowing… welcome to the world of quantum physics, where 'wave-particle duality' is commonplace and where the mere act of observing can affect the outcome of an experiment.

JARGON BUSTER

BLACK BODY
An object that is a perfect absorber of radiation is called a black body, hence the name. But if a black body is hot, it becomes a perfect emitter of radiation. So, seemingly paradoxically, the Sun is an almost perfect black body radiator.

DIFFRACTION
This is the process by which waves can bend around corners or spread out in all directions from a small hole or slit.

DUALITY
This is the way that quantum entities seem to be both particle and wave. Light 'waves' are associated with particles called photons; electron 'particles' are associated with waves.

ENERGY LEVEL
A quantum state, for example in an atom, that is associated with a particular energy. Electrons in atoms will sit on, or occupy, specific energy levels.

QUANTUM LEAP
The change of a quantum system, such as an electron in an atom, from one energy level to another. This happens without the system (electron) passing through any in-between state.

SUPERPOSITION
This is when a quantum system exists in a mixture of states. For example, an electron has a property called spin. On its own, the electron is in a superposition of spin up and spin down. It only 'collapses' into one state when it interacts with something. This is linked to the idea of quantum probability – there is a 50:50 chance of finding the electron in either state.

at a time, through an equivalent setup onto a screen like a television screen, where each electron made a single spot as it arrived, showing that it was a particle. But as hundreds of electrons were fired through the experiment, one after another, the pattern of spots that built up was an interference pattern, proving that electrons are waves.

Don't worry if you find your mind boggled by this. The physicist Richard Feynman used to say that "nobody understands quantum physics" – and he had a Nobel Prize for it.

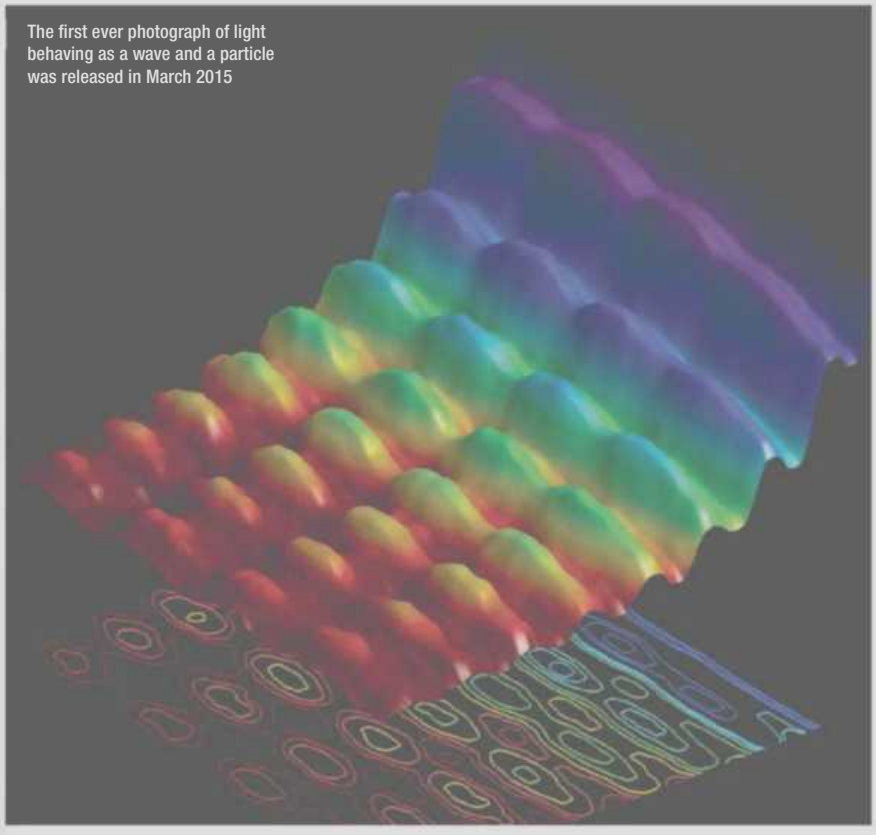
Are there practical applications?

Applied quantum physics is everywhere around us. Computer chips, including the ones in your smartphone, are designed using quantum physics and operate on quantum principles. The lasers used to read Blu-ray discs operate on quantum principles that were first worked out by Albert Einstein 100 years ago. Physicists have developed tools known as superconducting quantum interference devices, or SQUIDs, in which electron waves travel round a ring of metal about the size of a wedding ring. These are supersensitive detectors of magnetic fields, and are used in many different applications including the MRI scanners with which doctors can 'see' inside the human body.

The most exciting application of quantum physics today is in the new field of quantum computing. Ordinary computers are based on switches that can be either on or off (0 or 1); in contrast, a true quantum computer has switches (single atoms or electrons) that can be both on and off at the same time. This is a so-called superposition, which makes the computer immensely more powerful.

How does quantum physics explain the Sun's energy?

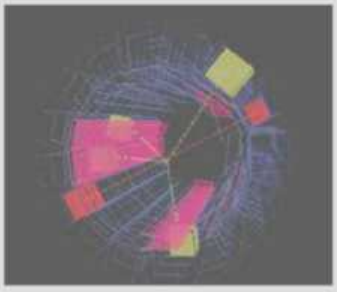
Stars like the Sun release energy as a result of a process called nuclear fusion. At its simplest, inside the Sun two protons (hydrogen nuclei) come together and fuse, then combine with other particles to make nuclei of helium. The helium has less mass than the particles that went into it, so energy is released in line with Einstein's famous equation, $E=mc^2$. Astronomers are able to figure out how hot the interior of



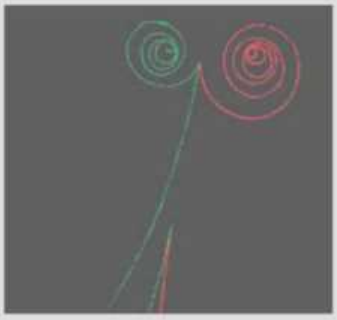
The first ever photograph of light behaving as a wave and a particle was released in March 2015

PHOTO: SCIENCE PHOTO LIBRARY X3

Researcher adjusting NanoSQUID device that changes temperature when hit by a photon



Model of a matter-antimatter annihilation event



Production of a matter particle, along with its corresponding antimatter

EXPLAIN IT TO A FRIEND

1. SCIENCE ON A TINY SCALE

Quantum physics describes the behaviour of very small things, like electrons and atoms. That's why we don't notice weird quantum effects in everyday life. But quantum physics explains how atoms and molecules work, including molecules like DNA. We need quantum physics to do everything from designing computer chips to genetic engineering.

2. EVEN EXPERTS GET CONFUSED

At the quantum level the distinction between waves and particles is blurred. Everything in the quantum realm is both wave and particle at the same time. Experiments designed to measure waves find waves, while experiments designed to measure particles find particles. What you look for is what you get.

3. PROBABILITY IS KING

Probability rules in the quantum world. If a single quantum entity, such as an electron, has a 'choice' of options, such as which of two holes to go through, it chooses at random. Einstein hated the idea that 'God plays dice', and did not accept this. But experiments show he was wrong.

the Sun must be in order to hold itself up against gravity.

But this then led to a puzzle. Because protons are positively charged, they repel each other and have to be moving very fast before they will collide and stick together. Classical physics said that the interior of the Sun is not hot enough for this to happen. Quantum physics provided the explanation. When two protons are close together, but not close enough to touch according to classical theory, quantum uncertainty means that there is a probability that they might actually touch. Another way of understanding this is to think of the protons as waves, reaching out to each other. Either way, the result is that the protons can fuse. They are said to tunnel through the barrier of classical electrical repulsion.

What is antimatter?

One of the strangest predictions of quantum physics is that for every type of particle, there should be an antiparticle that has its key properties reversed. The electron, for example, has a negative charge, while its antiparticle, the positron, has positive charge.

The physicist Paul Dirac was the first person to take this seriously, but when he published the idea in the 1920s he cautiously suggested that the required positive particle might be the proton, the only other particle known at the time. But in 1932 the physicist Carl Anderson discovered the tracks of positively charged particles with the same mass as electrons in a device known as a cloud chamber. This breakthrough earned him a Nobel Prize.

Dirac had been more correct than he had realised himself. It turns out that particle-antiparticle pairs (such as an electron and a positron) can be made out of pure energy in line with Einstein's equation, but when a particle and its antiparticle meet they annihilate each other in a puff of gamma rays. ■

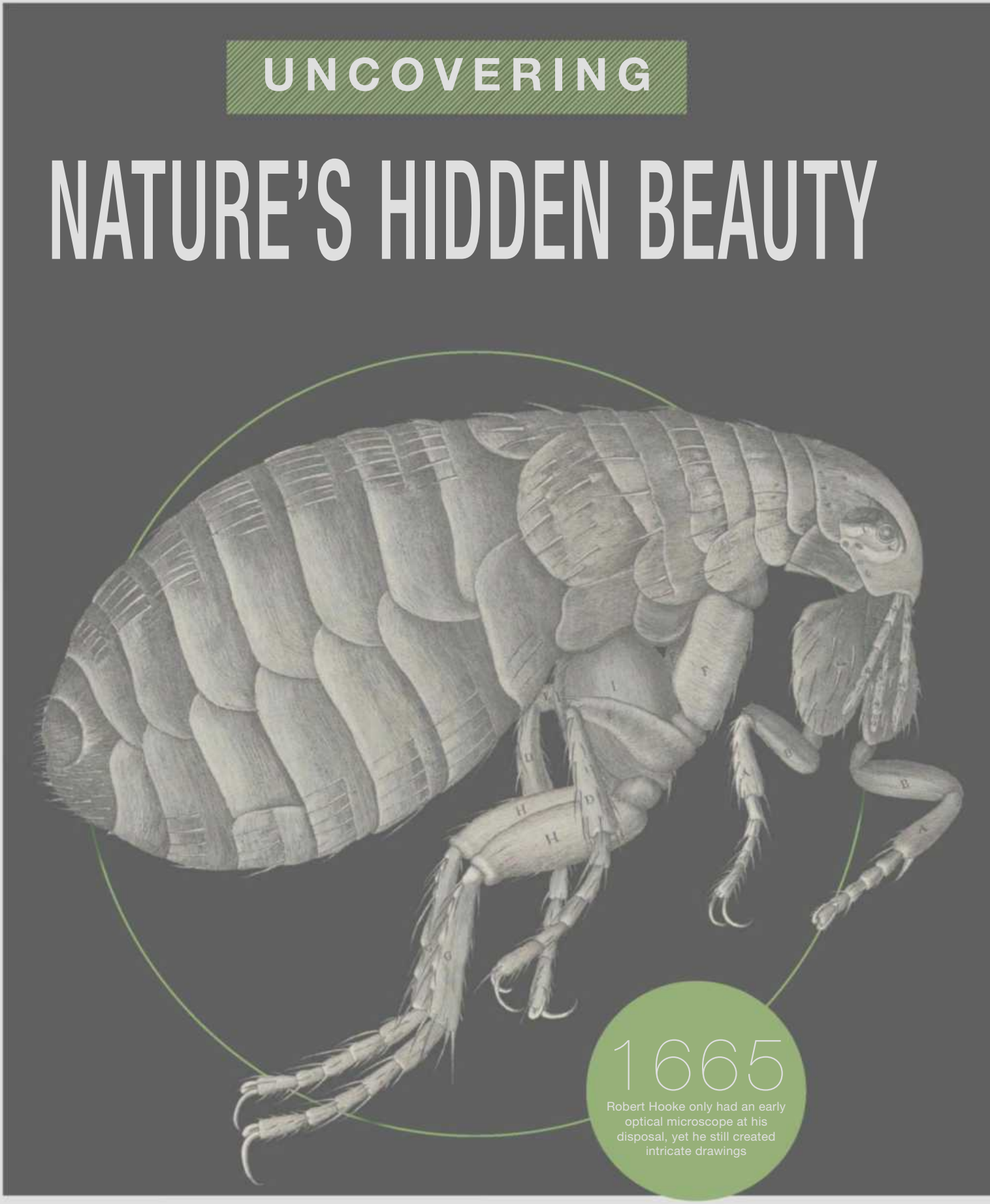
DR JOHN GRIBBIN is a science writer and astrophysicist

Quantum physics gives us free will! Without it you would have no choice about anything. It explains what life is and how my phone works.

IN ONE TWEET!

UNCOVERING

NATURE'S HIDDEN BEAUTY



1665

Robert Hooke only had an early optical microscope at his disposal, yet he still created intricate drawings

PHOTO: SCIENCE & SOCIETY, CORBIS

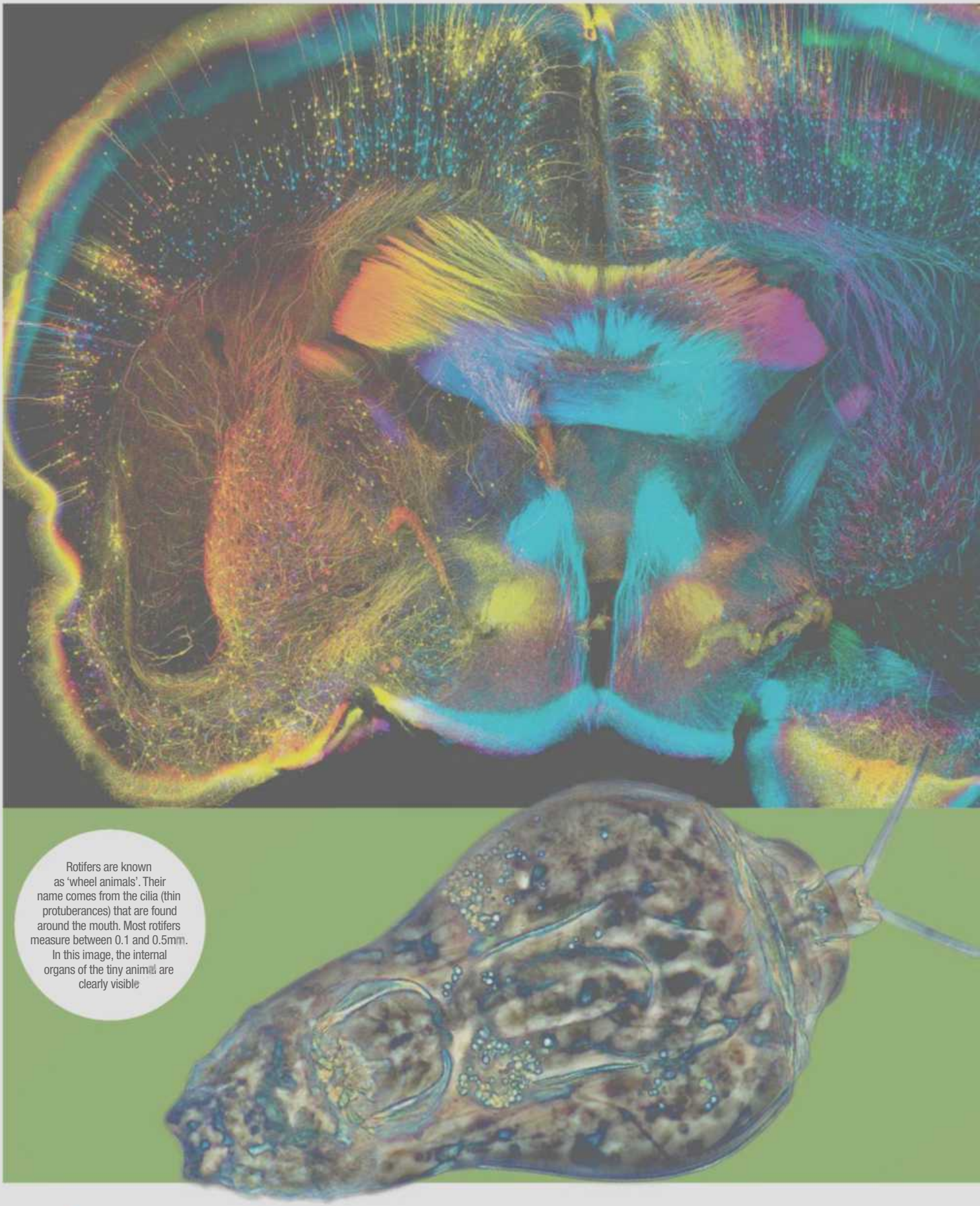
Robert Hooke's *Micrographia*, published 350 years ago, evolutionised the way we see the natural world. Michael Banks takes a closer look at the cutting-edge imagery shaping our knowledge today

Not many books claim to change the way we view the world, but a 1665 publication by the English physicist Robert Hooke did just that. The book was called *Micrographia* and featured some 60 drawings of animals and other objects, based on observations that Hooke made using his microscope.

While such microscopes had been around since the 1590s, it was *Micrographia* that first captured the public's imagination, advancing microbiology as a branch of science. Now celebrating its 350th anniversary, *Micrographia* has become a timeless classic, comparable in impact with Isaac Newton's *Principia* and Charles Darwin's *On The Origin Of Species.* "What makes Hooke's *Micrographia* so special is that it also contains the first use of the word 'cell' in biological terms," says Kim Findlay, Head of Bioimaging at the John Innes Centre in Norwich. While Hooke's humble microscope was a powerful instrument back then, it pales in comparison to some of its modern cousins that scientists now use to study the intricacies of the microscopic world.

2015

Today, it is possible to create detailed 3D images of specimens, such as this Oriental rat flea (Xenopsylla cheopis)



Rotifers are known as 'wheel animals'. Their name comes from the cilia (thin protuberances) that are found around the mouth. Most rotifers measure between 0.1 and 0.5mm. In this image, the internal organs of the tiny animal are clearly visible

PHOTO: WELLCOME TRUST, SCIENCE & SOCIETY X5, SCIENCE PHOTO LIBRARY

The neurones are coloured according to depth. Red (top), orange, yellow, purple, blue and green (bottom)

Brought into focus

This is a section of a mouse brain that was imaged using confocal microscopy. The psychedelic strands running through it are neurones, which have been colour-coded according to depth. This image, taken by Luis de la Torre-Ubieta, was part of his research investigating how neurones take shape in their development. Confocal microscopy was developed by computer scientist Marvin Minsky from the Massachusetts Institute of Technology in the mid-1950s. In conventional microscopy, although a small part of the sample is illuminated at one time, some of the reflected light scatters, which can result in slightly blurry images with a top resolution of 200nm. Confocal microscopy gets around this problem by adding a small pinhole aperture, which only lets in light from the desired focal spot of the sample. This produces sharper pictures, getting close to a resolution of around 100nm.

Scientists have used confocal microscopy to view muscle fibres in detail, and to show how living cells grow and divide.

Seeing the invisible

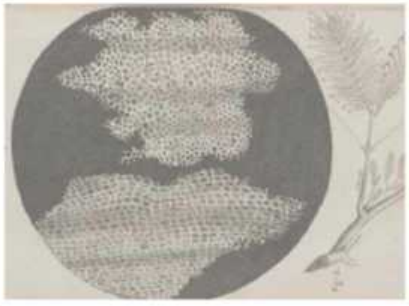
Here is a tiny aquatic animal known as a rotifer. Many microscopic objects such as rotifers, bacteria and cells are colourless or transparent, making them tricky to image directly. It's not always possible to stain such samples as it could harm them. This is where the phase contrast microscope comes in. The technology was developed by the Dutch physicist Frits Zernike in the 1930s, who was later awarded the 1953 Nobel Prize in Physics for his work.

When light travels through a transparent or colourless object, there is a slight alteration in 'phase' – a measure of how much a light wave changes compared to the uninfluenced light. The phase contrast microscope translates this change in phase into a difference in brightness, so that transparent objects shine out in contrast to their surroundings. The phase contrast microscope is useful because it allows organisms and cells to be viewed while they're still alive and has a top resolution of around 200nm.

HOOKE'S KEY DISCOVERIES

Fly's eye

When investigating the eyes of insects, Robert Hooke chose a drone fly as it had "the largest cluster of eyes in proportion to its head". He estimated the number of "hemispheres" in his sample at 14,000.

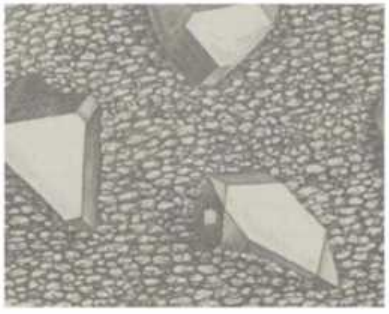


Plant cell

During his observations of the internal honeycomb-like structure of this slice of cork, Hooke first coined the biological term 'cells' to describe the individual repeating components. He saw similar structures in other plants too.

Urine crystals

In his typically curious fashion, Hooke put samples of urine under the microscope noting that he had "often observ'd the gravel or sand of urine". Under the microscope, he found that the crystals looked yellow, red, brown and white.

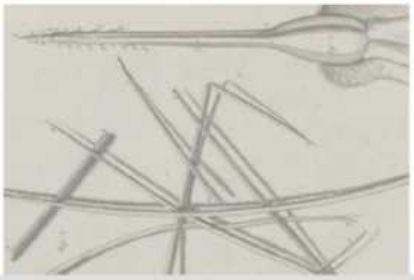


Nettle hairs

Hooke decided to put nettle leaves under his microscope in order to figure out exactly what it was that gave them their sting. He correctly determined that the "bodkin-like" bristles were responsible.

Bee sting

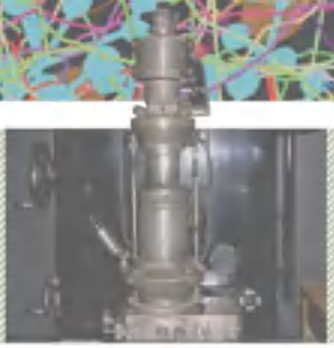
This intricate drawing by Hooke shows the barbs along the sides of the bee sting's shaft. He commented that they were "like so many thorns growing on a briar". He also drew the bulbous venom sac at its base.



The blue and red circles on this image are synapses, which are the contact regions between two neurones. The orange ones are points of interest, such as mitochondria

HISTORY REVEALED

Key breakthroughs that transformed the world of microscopy



1931
Electron microscope

The properties of visible light mean that it is not possible to resolve features less than about half a micrometre. The invention of the cathode ray tube made it possible to create a microscope that used beams of electrons instead of light. This new method of microscopy was capable of resolutions of 50nm.

1934
Phase contrast microscope

This microscopy technique allows scientists to observe features of biological specimens that would ordinarily be transparent to an optical microscope. The microscope works by taking advantage of the fact that light travels at different speeds through different materials. It was developed by Frits Zernike (pictured).

PHOTO: WELLCOME TRUST, SCIENCE PHOTO LIBRARY X3, GETTY, J BREW/WIKI, APS PHYSICS

Joining the dots

This is a reconstruction of the nervous system of a fruit fly larva, with images taken by a Transmission Electron Microscope (TEM).

An animal's nervous system controls everything it does, from moving, to thinking, to breathing. The yellow line through this image represents a neurone that detects vibrations, surrounded by hundreds of others. This image was taken as part of research to map out the neural circuits of animal brains.

TEM is the undisputed king of microscopes, allowing scientists to image individual atoms with a resolution better than 0.1nm. The first TEM was built in 1931 by the German electrical engineer Max Knoll and the German physicist Ernst Ruska, who later went on to win the Nobel Prize in Physics in 1986. A TEM strikes a sample with an electron beam that is focused using magnetic fields. It requires a very thin sample (around 100nm thick) so that the beam can pass through it. At the bottom of the microscope, electrons hit a phosphor screen, which gives rise to visible light. Electrons scattered by atoms in the sample cannot make it to the bottom, resulting in a 'shadow image' of the specimen. Regions of the sample are displayed differently according to what elements are present – paler for lighter elements, darker for heavier ones.

The samples need to be put in a vacuum inside the microscope because molecules in the air would scatter the electrons, giving no image. Therefore, it is not possible to study live samples in an electron microscope.

1951
Field ion microscope

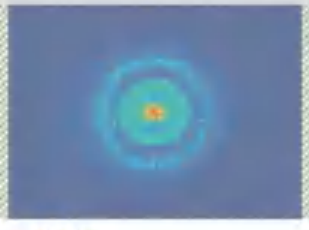
Erwin Müller (pictured) invented the first microscope capable of imaging atoms. The metal under investigation is made into sharp tip and is placed in a vacuum with a tiny amount of imaging gas. A high voltage is applied to the tip, causing the gas atoms near it to become ionised. They are then repelled towards a screen to form an image.

1981
Scanning tunneling microscope

STMs use quantum tunneling to create images at an atomic level. The technique works by scanning a fine tip across a surface of the material under investigation. Electrons can 'tunnel' across the empty space creating an electric current that is then used to form an image.

1986
Atomic force microscope

These microscopes were developed from scanning tunneling microscopes. They scan a very sharp tip across the surface of a sample and maintain the force between the two at a constant level. The bending of the tip due to atomic forces is then detected and used to create an image of the surface at a high resolution.



2009
Quantum microscope

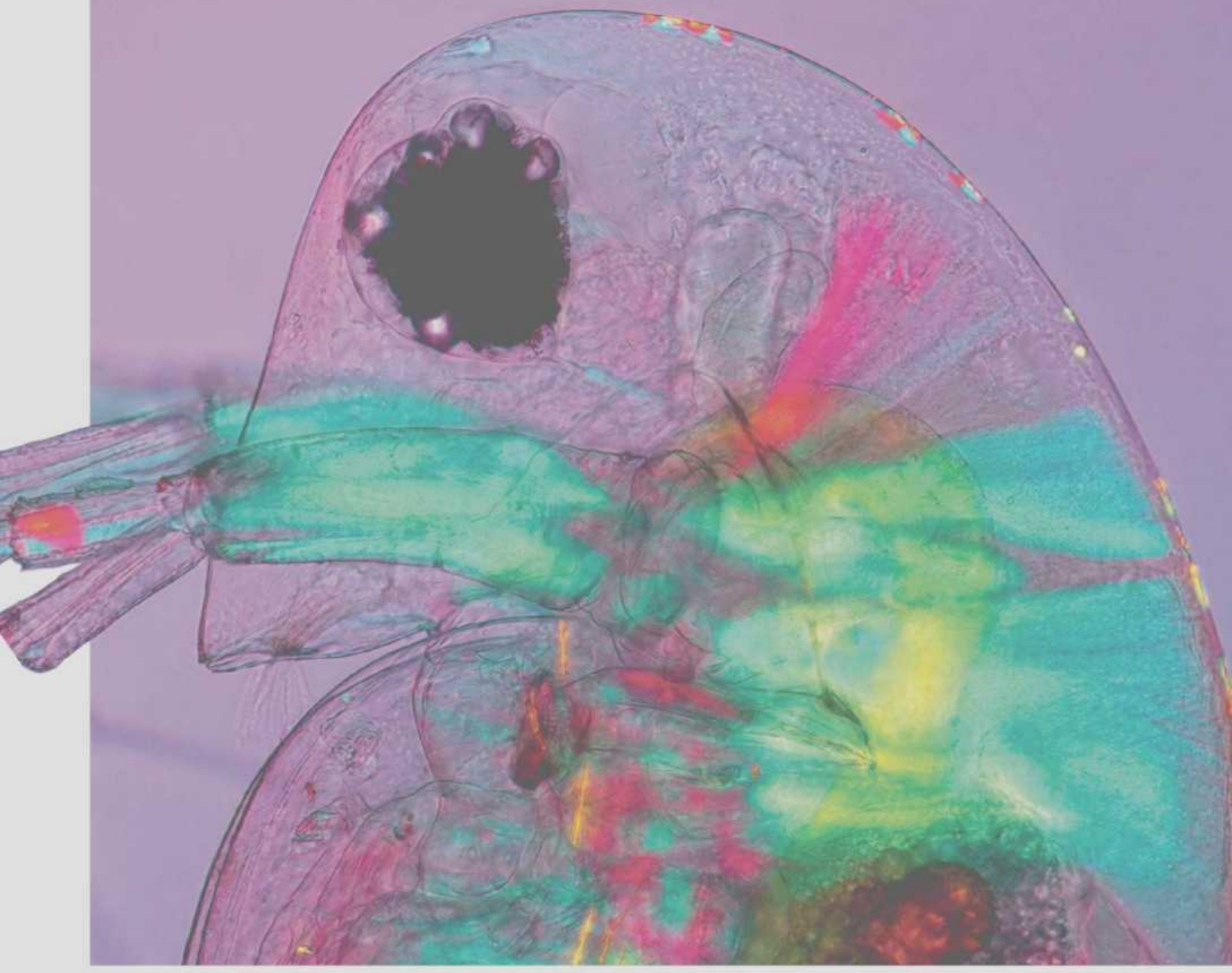
A Dutch team used photoionisation to produce this image showing the nucleus and electron orbital of a hydrogen atom. They placed the atom in an electric field and hit it with lasers. This caused the ionised electron to escape from the atom and strike a detector, building an image of the atom's electron orbitals.

Polarised plankton

This colourful creature is a species of water flea. These are tiny crustaceans often found in freshwater environments. It was photographed using a polarised light microscope. This kind of microscope allows you to see 'birefringent' structures (those that bend light in two directions) more clearly. Collagen and crystals are two such structures. In the case of this water flea, this technique allows us to see its form and inner workings in sharper contrast.

Polarised light microscopy takes advantage of the way that light behaves. Light travels as a wave, which can oscillate in many different orientations. But it is possible to 'polarise' light so that it is made to fluctuate along one single axis. This type of light allows us to study structures that appear different when viewed from multiple angles.

Polarised light microscopes have a top resolution of 200nm are often used in the fields of geology, medicine and biological research.



Daphnia water fleas, like the one pictured, measure up to 5mm. They live in most types of freshwater and are an important part of the food chain

The compound eye of the earwig, like most insects, consists of many photoreceptor units called 'ommatidia'

This is an image of a weevil created with a SEM

The third dimension

This image of an earwig was created with a Scanning Electron Microscope (SEM). The photographer used LEDs to illuminate the insect in a unique way, taking inspiration from portraits painted by artists in the 17th Century.

While light offers a powerful way to take scientific images, it cannot resolve anything much smaller than the wavelength of light. In fact, it was long thought that anything on an atomic scale would be impossible to see since the wavelength of light is thousands of times larger than the distance between two atoms. That changed with the introduction of the SEM, which was pioneered in the late 1940s by Charles Oatley and colleagues at the University of Cambridge.

The SEM consists of a source of electrons – small subatomic particles that have wavelengths less than 1nm – that are focused into a tight beam that strikes the surface of a sample. This beam causes a tiny part of the sample's surface to emit electrons, which are picked up by a detector to create an image of the shape of the object under study. If a sample were completely flat, the image would be monotone. As soon as there is some 3D shape to the surface of the sample, more electrons are detected from the side of the sample that's facing the detector, giving rise to increased brightness.

SEMs have a resolution of about 1nm and allow scientists to determine elements in a sample and even fabricate structures on a nanometre scale. ■

DR MICHAEL BANKS is the news editor of *Physics World*, which is the magazine of the Institute of Physics

discover MORE!

To see more stunning images from Robert Hooke's *Micrographia*, visit bit.ly/NaturesHiddenBeauty

Nature's Weirdest Events

Showing that fact can often be stranger than fiction, this mind-blowing series returns to investigate nature's most surprising stories

Bee making multi-coloured honey, blue and green

PHOTO: VICTORIA BROMLEY

PHOTO: VICTORIA BROMLEY

Two Headed Snake

Two Headed Snake, close up

PHOTO: VICTORIA BROMLEY

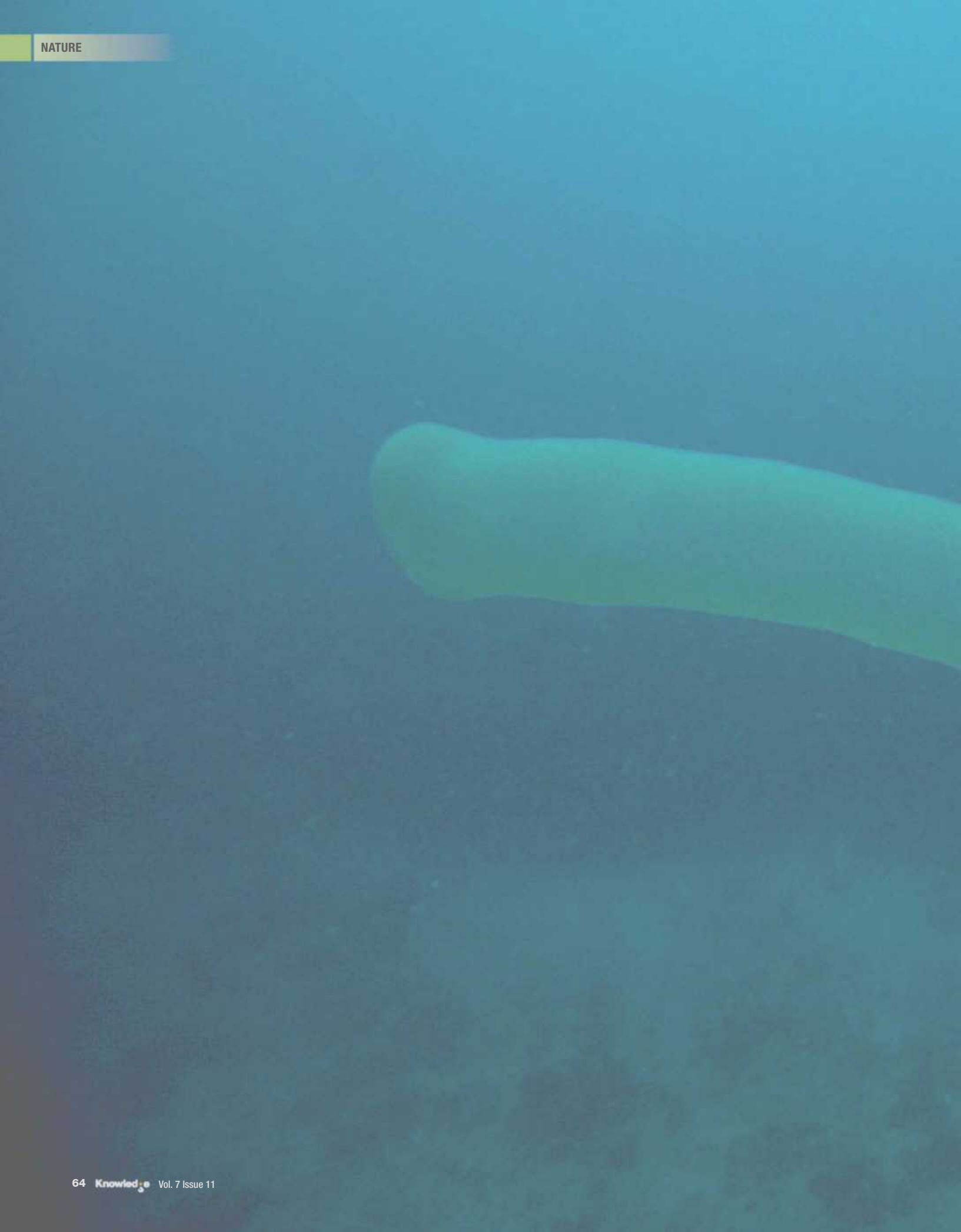
Two Headed adder in the grass

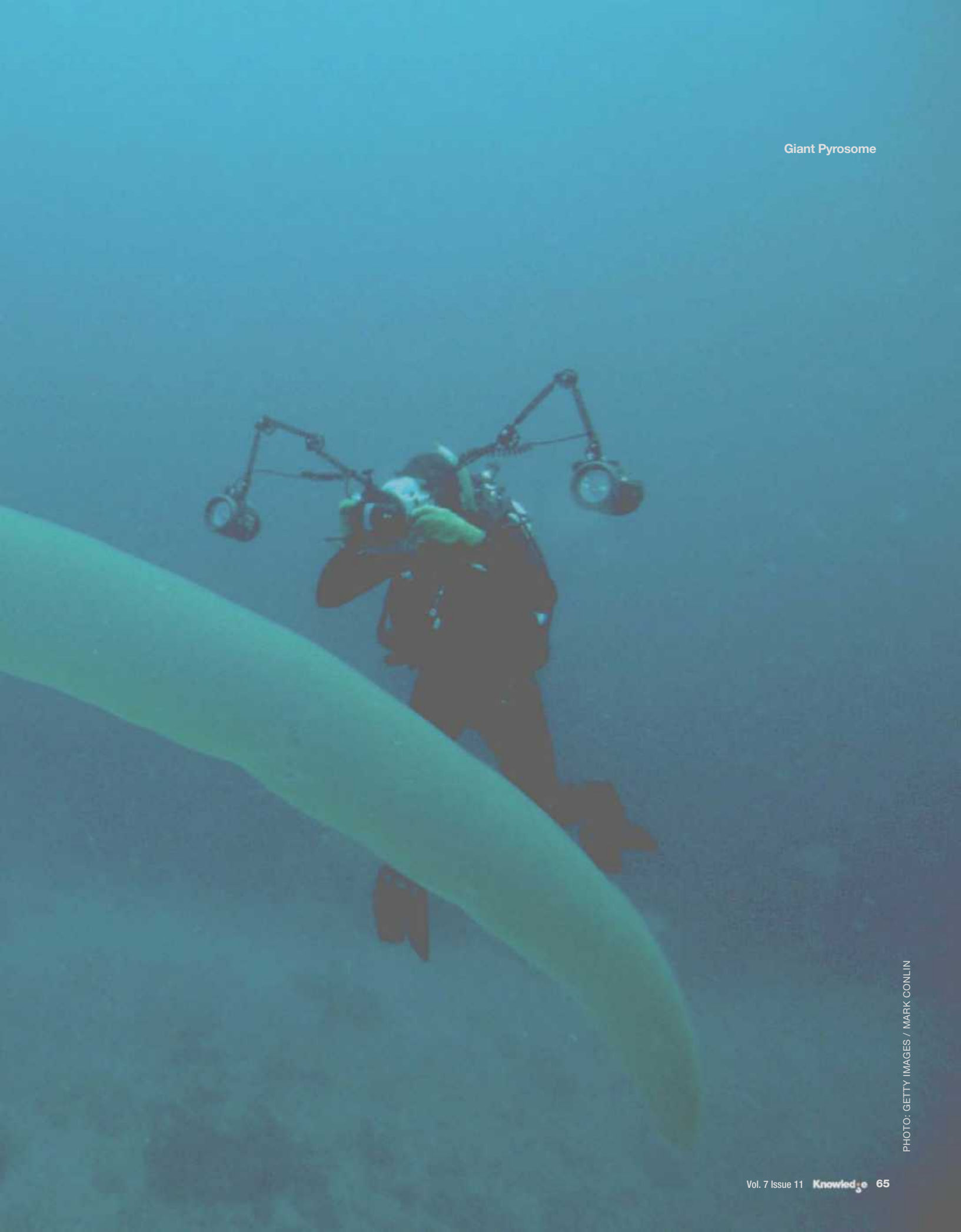
PHOTO: GORDON CROOK

The natural world is full of shocking sights and wonderfully weird creatures and this fascinating programme travels the globe to showcase some of the most mind-blowing of them all. Nature's Weirdest Events uses a combination of BBC Natural History Unit archive, amateur footage, eyewitness statements and expert analysis to investigate nature's most curious and surprising stories. When it comes to nature, this series proves that fact can often be a lot stranger than fiction!

Bleeding Birch Tree

PHOTO: MATT WEST





Giant Pyrosome

PHOTO: GETTY IMAGES / MARK CONLIN

PHOTO: ROBIN SMITH

Two Toned Lobster

Close up of Wolverine Frog

PHOTO: NADEGE LAICI

Two Toned Lobster, close up

© VICTORIA BROMLEY

PHOTO: BERTRAND LENCLOS

Close up of Wels Catfish preying on pigeons

PHOTO: FRANK GLAW

Brookesia Micra Juvenile on finger

PHOTO: FRANK GLAW

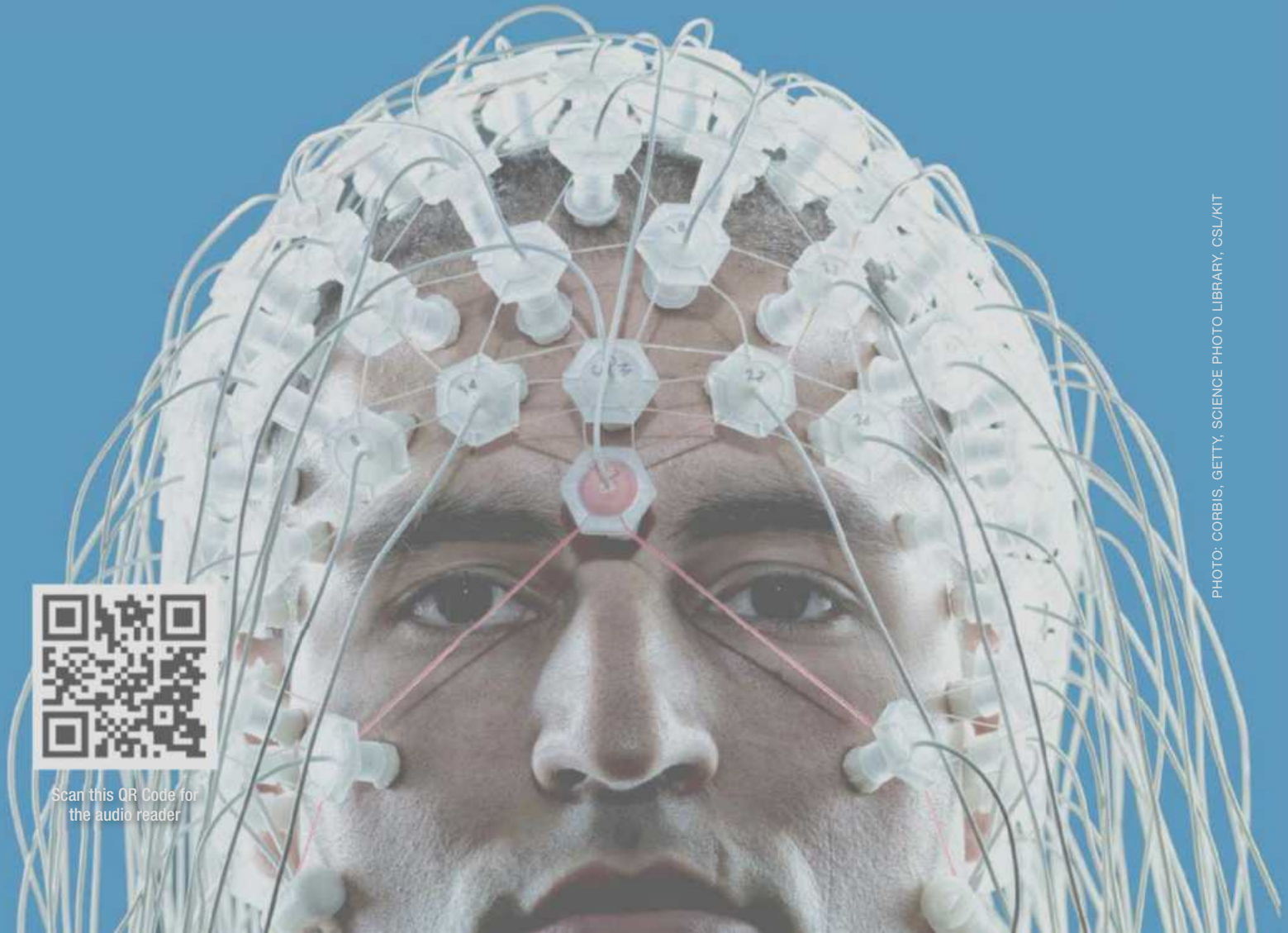
Brookesia Micra, miniature chameleon; weird design adaptations

PHOTO: BERTRAND LENCLOS

Aerial view of Wels Catfish sneaking up on pigeons

FACEBOOK WANTS TO READ YOUR MIND

Facebook's Mark Zuckerberg recently claimed that technology will one day allow us to update our friends via thought. But as Rita Carter reveals, machines can already decipher our brains



Scan this QR Code for the audio reader

PHOTO: CORBIS, GETTY, SCIENCE PHOTO LIBRARY, CSL/KIT

Consider a selection of stereotypical movie scenes:

1. A witness to a crime walks hesitatingly along a line of blank-faced characters trying to identify the culprit. 2. A defendant pleads with the jury from the dock: " I didn't do it – believe me!" 3. A victim screams: "All right – I'll talk!" as some vile instrument of torture is applied to their flesh.

Now, in your mind, imagine the witness, defendant or victim lying in a brain scanner. Nearby, an image forms on a monitor. It's fuzzy at first, but forms into a clear picture – maybe a face, an event or a string of words. The scanner has read the person's mind and presented its contents.

The second type of scene has been a sci-fi staple for decades. But recently, 'mind reading' by brain imaging has taken some big steps into the real world.

German and US researchers recently produced speech that was communicated by a patient undergoing brain surgery. The words in the recording were translated from a readout of the electrical patterns generated in the patient's brain.

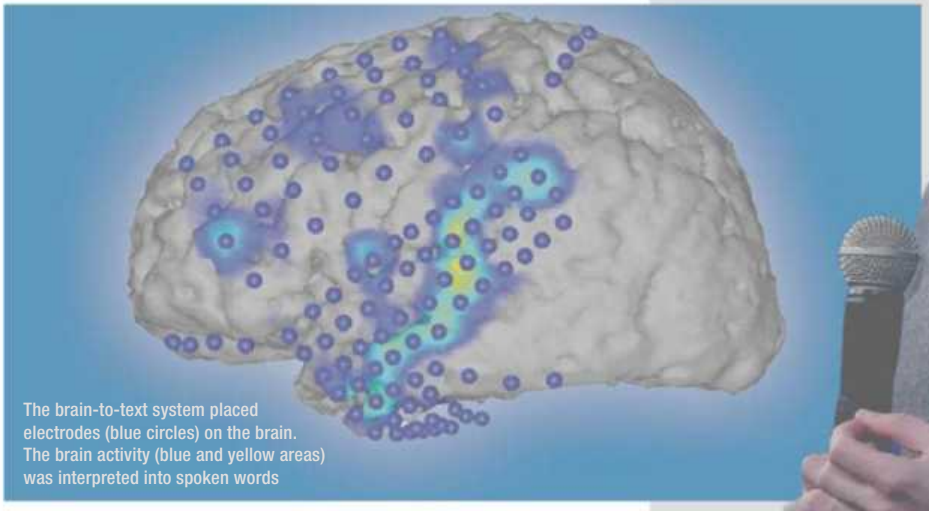
This brain-to-text study is the latest to demonstrate that neurotelepathy – knowing what a person is experiencing by interpreting their brain activity – is a reality, even if it is still relatively crude. Last year, a group of Yale researchers produced digital reconstructions of faces that were being viewed by people in an fMRI scanner (see 'What is fMRI?'). Again, the source of the images was the pattern of activity detected in the viewers' brains. The published results suggest the reconstructed faces are as recognisable, or more so, than traditional photofits.

Prof Marvin Chun, who ran the study in his lab at Yale, says it has finally given him an answer to the question so often asked by strangers when they learn he is a psychologist: "They want to know if I can read their mind,' he says. "Now I have an answer. Yes. If I can get them in a scanner, I can."

So far, there is a limit to what can be read. Alan Cowen, the Yale PhD student who designed the study, stresses that the volunteers willingly conveyed the information that was extracted. "We can only read active parts of the brain," he explains. "So you couldn't read passive memories – you would have to get the person to imagine the memory to read it. It's a matter of time, and eventually, maybe 200 years from now, we'll have some way of reading inactive parts of the brain. But that's a much harder

Above: Prof Martin Chun boasts that he can read minds Below: EEG electrodes monitor brain activity

"One day, I believe we'll be able to send full, rich thoughts to each other directly using technology"



The brain-to-text system placed electrodes (blue circles) on the brain. The brain activity (blue and yellow areas) was interpreted into spoken words

Could Facebook's Mark Zuckerberg be correct?

problem, as it involves measuring very fine details of brain structure that we don't even really understand."

Private thoughts

This doesn't put paid to the issue of privacy, however, because you don't necessarily have control over which parts of your brain are active. In a 2013 study, even more Hollywood-like, a Japanese group managed to recreate dreams. Brain activity was recorded from volunteers. This was then translated into a video of what they were likely experiencing during Rapid Eye Movement. The resulting films were more detailed than the dreamers' own recollections of their experiences.

Neurotelepathy is possible because the location of brain functions is pretty consistent across individuals. Almost anyone who looks at a face will show activation in an area on the left of their brain, just behind the ear. Looking at inanimate objects stirs activity in a different area. Thinking sad thoughts will activate different areas to happy thoughts. Saying 'aaaaah' involves different neurones to saying 'teeeee'.

Of course, there are differences between individuals. If you and I hear the word 'moon', our brains will not respond identically. For you, the word may jog images of astronauts, while in me it might trigger the notion of cheese. But activity correlating to hearing 'oooo', and imagining a silver disc will be common to us both. If you build a big enough database of different brains responding to the same things, you can arrive at a 'signature' for each stimulus.

One of the first studies to show that this method works was carried out at MIT in 2000. A group led by Prof Nancy Kanwisher showed images to volunteers while they were being scanned, then examined the readouts.

"Just by eyeballing the data, I correctly determined in over 80 per cent of the trials whether the subject was imagining faces or places," says Kanwisher. "I worried for a long time before we published these data that people might think we could use an MRI to read their minds. Would they not realise the results obtained in my experiment were for a specific, constrained situation? That we used faces and places because we know which highly specific parts of the brain process those two categories? That we selected only cooperative subjects who were good mental imagers? And so on. I thought, 'Surely, no one would try to use fMRI to figure out what somebody else was thinking?'"

But of course, people would. "One day, I believe we'll be able to send full, rich thoughts to each other directly using technology," announced Facebook CEO Mark Zuckerberg during a recent Q&A session. "You'll just be able to think of something and your friends will immediately be able to experience it too."

There is a massive practicality gulf between current experiments and Zuckerberg's vision. The brain-to-text experiment, for example, involved placing electrodes

"Movie-style thought transference is currently impossible, but experimental neurotelepathy is creeping into use"

FACE FACTS

On the left are the original faces that were seen by volunteers as part of the Yale study; on the right are versions created by a computer after reading their minds

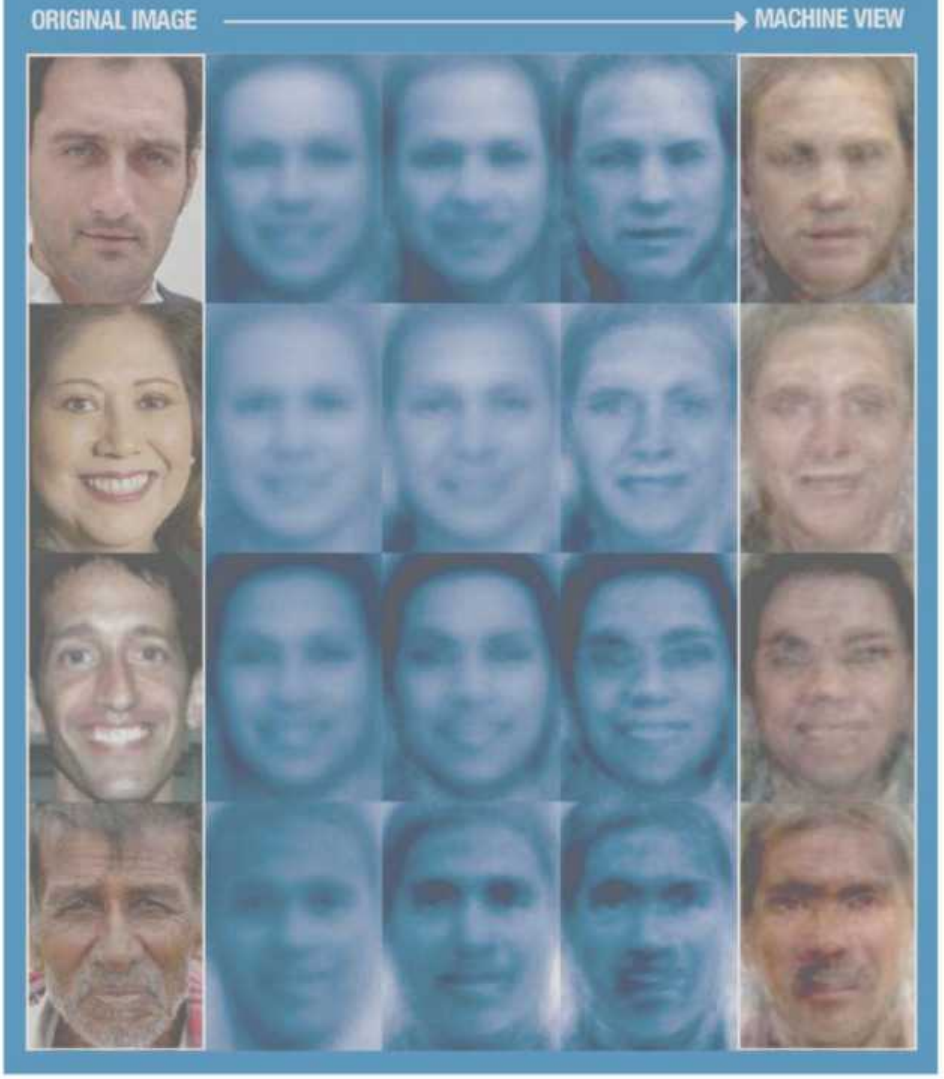


PHOTO: ALAN COWEN, SCIENCE PHOTO LIBRARY

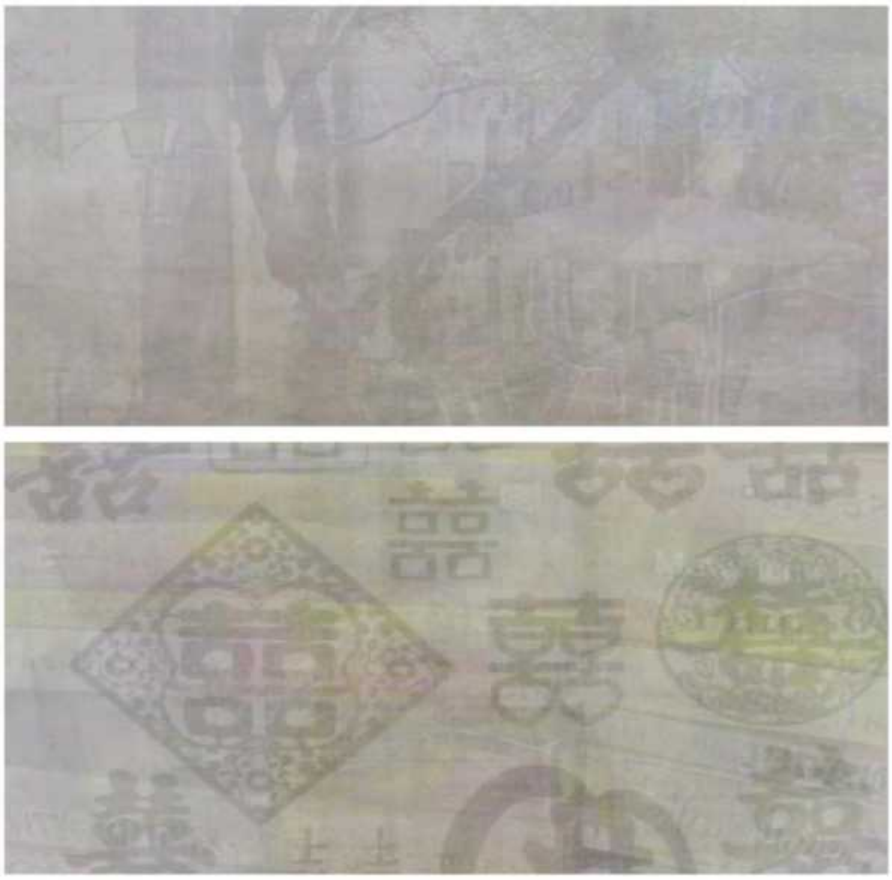
directly on the brains of patients during surgery. Meanwhile, the Yale face recognition study depended on a huge IT development project and hours of tedious fMRI scanning for the volunteers.

Even the most gung-ho neuroscientists hedge their bets about the future of neurotelepathy. Prof Jack Gallant at the University of California, Berkeley believes that thought-conveying helmets will eventually exist, but not for a long time.

"The most optimistic estimates are that you can recover one-millionth of the information that's available in the brain at any given point in time," Gallant says. "It's probably smaller than that. Where we are today is just measuring a pale shadow of what you could potentially measure, if you had a better measurement technology."

Health help

Even though movie-style thought transference is currently impossible, experimental neurotelepathy is slowly creeping into use. A 'painometer' is being developed that makes a person's suffering visible to others. The consciousness level of patients undergoing surgery has been monitored to ensure they don't start to feel the surgeon's knife. Locked-in syndrome patients have been able to



In a 2013 Japanese study, researchers managed to visualise the dreams of volunteers sleeping in an fMRI machine. These images were taken 31 seconds before waking (top) and 12 seconds before waking (above)

WHAT IS fMRI?

Functional Magnetic Resonance Imaging (fMRI) shows what the brain is doing, as well as how it looks. Volunteers in fMRI experiments typically carry out a cognitive task, such as responding to stimuli, or calculating, recalling, or imagining something. Meanwhile, the scanner measures the blood flow to and from different parts of the brain and superimposes it onto an anatomical picture of the brain. The areas pulling in most blood are assumed to be those that are most active. This is because blood carries oxygen, which is the 'fuel' that brain cells use to generate electricity.

fMRI is the most common technology used to correlate brain activity with our thoughts, responses and perceptions. It seems to be safe and it's good at pinpointing location. Other techniques, such as non-invasive EEG, in which scalp-mounted electrodes detect signals from the underlying brain, are faster but less precise.

This technique allows scientists to measure brain activity. It is safe, easy to use, and quickly gives excellent results

Here, there is increased blood flow in the right motor cortex of the brain because the subject is moving their left hand

MIND READERS ON TRIAL

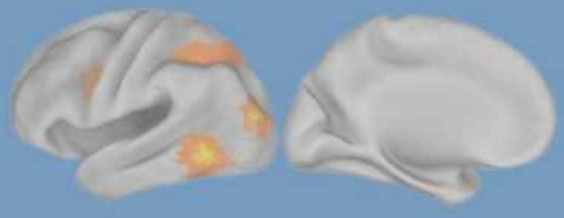
Could we see brain scanners used in criminal cases?

In 2008, an Indian court sentenced 24-year-old student Aditi Sharma to life imprisonment for murdering her ex-fiance. An EEG-based lie detection test was accepted as key evidence.

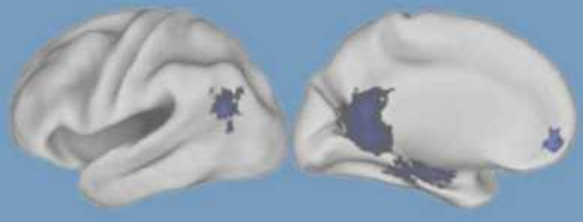
Brain-based lie detection has often been put before courts, but in most countries it is rejected as unreliable. In fact, India has since declared it inadmissible. One issue is whether the brain activity seen in lying is indicative of deception.

A major neural 'marker' of deception is high activity in the frontal brain areas that concoct stories. The assumption is that lying involves making things up while telling the truth does not. In standard lab tests the marker is pretty reliable, but a similar pattern of activity can occur in other situations giving false results. In one study, volunteers were shown a series of cards and asked to select one without saying which. When they saw the card again and were asked if it was the one they had noted, their brains reacted similarly whether or not they were lying about having selected it. This suggests that merely investing something with meaning may cause your brain to react to it in a different way to other things.

A second question is whether the lie detector itself can be deceived, and a study at the Memory Lab at Stanford University showed how the system can be beaten. Twenty-four volunteers were shown 200 novel faces on one day. The next day, they were shown the faces again, along with 200 new faces mixed in. They then had to hide their memories – when they saw a familiar face, they had to say they didn't recognise it, and also had to claim they recognised unfamiliar faces (see image). Their brain activity convinced the machine that they were telling the truth when they were lying. Until lie detection cracks these problems, it is unlikely to appear in criminal courts. Given current progress, though, this may not take long. Meanwhile, Sharma has been released from prison pending appeal.



These images show the areas of the brain that lit up when someone pretended to see a familiar face for the first time



These images show the areas of the brain that lit up when someone pretended to recognise an unknown face

PHOTO: JAMES DUNCAN DAVIDSON/TED

Prof Nancy Kanwisher examined brain readouts from willing volunteers, but was concerned about potential backlash

"Surely, no one would try to use fMRI to figure out what somebody else was thinking?"

communicate simple thoughts such as 'yes' or 'no' just by thinking them. These applications have succeeded because the 'signatures' of the experiences they convey are less complex than those associated with face perception or speech. But the principle of reading information from a brain is already established.

Mind-reading devices that benefit the sick are ethically unchallenging, but the idea of technology that can look into your head and see things you would rather keep to yourself is a different matter.

So far, the only brain reader to get out of the lab is the lie detector based on EEG or fMRI. It has been around for a decade. Once, in India, it helped convict a man for murder, though UK and US courts generally refuse to allow it. The companies that sell it claim it can tell if a person is lying with 90 per cent accuracy. Yet these results come from closely controlled experiments and it is far less effective in the real world.

Legal aid

Sooner or later, neurotelepathy will almost certainly be good enough for law enforcement and intelligence agencies. Many find the prospect scary, but the cost of breaching mental privacy might outweigh the harm currently being done by our inability to see inside people's heads. Conscious eyewitness recall is terrible, and mistaken recognition is responsible for more convictions of the innocent than all other factors combined. Most people can detect lying at little better than chance. And if information must be extracted, surely brain scanning is more humane than torture? Like all technology, its value will depend entirely on how it is used. ■

RITA CARTER is a science lecturer, broadcaster and writer who specialises in the human brain

QUESTIONS AT THE FRONTIERS OF...

MATERIALS SCIENCE

Intriguing new substances could vastly improve the efficiency of devices such as batteries and solar panels. **Dr Paul Coxon** lifts the lid on this hot area of research

Perovskite crystals are incredibly efficient at absorbing light, which could allow the development of improved solar cells

Q How can we get more energy from the Sun?

It's said that the Earth receives enough energy from the Sun in one hour to meet our energy needs for a whole year. If we could turn just a tiny percentage of this into electricity, it would help to massively cut down on energy sources such as coal, gas and oil, which produce greenhouse gases when burnt. Over the past five years there has been an incredible boom in solar photovoltaic (PV) capacity around the world, mostly led by China and the US. Over 90 per cent of this capacity comes from silicon-based solar cells, the cost of which has been steadily falling due to improvements in manufacturing.

Silicon solar cell technology has existed since the 1950s and has risen from 6 per cent efficiency to around 24 per cent today. These improvements have largely been gained through better engineering of the materials that make up the cell and by enhancements to anti-reflection layers applied to the topmost surface, which capture more light.

Now there is a new class of materials called perovskites, which have gone from efficiencies of 4 per cent to nearly 20 per cent in just five years. These are crystals of inorganic-organic compounds with structures that are extremely efficient at absorbing light. They can absorb a wider range of wavelengths than silicon and these free charges can separate quickly and travel relatively long distances through the material before combining together. The exact physics behind why perovskites work so well in converting light to electricity is still under debate by researchers, but they are now one of the hottest areas of research in materials science today. They are very simple to make at room temperatures with standard chemical techniques, which potentially makes them easy to produce at large volumes.

However, perovskite solar cells have a major drawback – they are incredibly unstable. The materials begin to break down when exposed to moisture, oxygen or UV radiation. This causes the perovskite material to degrade into other compounds that are less efficient at absorbing light and/or converting it to electricity. Efforts are now turning towards ways to address these problems by improving the encapsulation of the perovskite films and environments in which they are prepared.

Q Will we ever have everlasting batteries?

Energy storage, particularly the development of new batteries, is a booming industry. Improving battery power and efficiencies is one of, if not the biggest challenge in materials science today, drawing in researchers from a variety of fields. Batteries are used in so many areas of our lives, but they're often overlooked and we only notice them when they run out. Every new phone and laptop manufacturer boasts about how long their devices last between charges, yet – for some – the rate of improvement in battery technology is still too slow. The last major revolution was the introduction of lithium ion (Li-ion) batteries in the 1990s. In contrast, CPU speeds and memory capacities have increased at a far greater pace.

Li-ion batteries are much lighter than traditional lead batteries and are the preferred type for modern devices. Li-ion cells have a high energy density, are easy to maintain and can be recharged. Yet they have drawbacks: they are fragile and require a protection circuit to operate safely. Many of the advances in Li-ion

PHOTO: SCIENCE PHOTO LIBRARY

batteries have been in improving the chemical combinations of the battery components so they can survive more charge-recharge cycles. These practical, incremental changes have cut the cost of standard Li-ion batteries by half and have increased energy capacity by 60 per cent in just five years. Attention is now turning to more radical ideas such as aluminium-air batteries with 40 times the energy density of Li-ion. These promise to last two weeks between charges and are recharged by topping up with water. Aluminium is the anode and air acts as the cathode with an electrolyte between. Air reacts with the electrolyte and anode to form aluminium hydroxide and release electrons. The major limitation is the aluminium, which eventually corrodes and needs to be replaced over time. These will likely find applications in electric cars and are expected to make their commercial debut in the next year.

Q Are high-temperature superconductors an impossible dream?

In the future, advanced materials will help us generate energy cleanly and store it cost-effectively. But they could help us transport it too. Superconducting materials have the potential to dramatically change everything that relies on electrical power. Around 10 per cent of all UK electricity generated is currently lost due to resistance in metal transmission cables. Superconductors can carry electric current without any resistance, which means they're incredibly cost-effective to run and make the idea of lossless transmission lines a tantalising prospect. They are already used in some specialist areas, for example as magnets for MRI machines or particle accelerators like CERN's Large Hadron Collider.

However, superconductors must be cooled to very low temperatures just over 0°K (-273.2°C) with liquid helium. But helium is expensive and supplies are low – so the challenge is to develop superconducting materials that conduct at room temperatures. In the early days, superconductivity was known only in a few metals. By the 1980s, physicists had discovered a new class of superconductors based on ceramic materials that were superconductive at higher temperatures. One such ceramic material, yttrium barium copper oxide (YBCO), has attracted special attention because it superconducts at 93°K (-180.2°C). This higher temperature can be reached cheaply with liquid nitrogen.

YBCO's structure allows the electrons inside to pair up. This helps them navigate through the material without colliding and losing energy, which is the essence of superconductivity. Recently, German researchers have reported that hitting YBCO with ultrafast infrared laser pulses causes the material to become a superconductor at room temperatures – but only for a few picoseconds. This may offer a route to superconductivity at room temperature without the need for cooling. There's still a long way to go, and some interesting physics will be revealed along the way, but materials science will be at the forefront of this intriguing challenge. ■

DR PAUL COXON is a physicist at Cambridge University. He researches new nanomaterials to improve the light capturing efficiency of solar cells

THE SECRET LIVES OF WASPS

Wasps buzz their way into the British tabloids every summer. But Adam Hart says that these striped insects are horribly misunderstood...

5cm is the maximum length of the European hornet

LIFE CYCLE

At the end of summer, the queen wasp mates and then overwinters in a state of torpor. In the spring, she wakes up and looks for a suitable place to start a nest. She uses wood pulp to build a small nest in which she can rear her first batch of female workers. Workers, who don't reproduce, rapidly take over the running of the colony while the queen lays eggs that will develop into more workers.

As the season progresses, the workers produce new potential queens by feeding some larvae richer food. The queen (and some workers) can also lay unfertilised eggs that develop into males. The reproductive males and females mate; the queens overwinter while the males die. As the colony winds down in early autumn, the remaining workers also die.

POPULATION

Wasp populations tend to fluctuate, and whether it is a good or bad year for wasps is the subject of much media attention. In fact, there seem to be two-year and possibly seven-year cycles that are driven by a combination of factors related to the biology of wasps and, crucially, the climate over the preceding year. For example, cold winters are good for wasps because the queens remain in the relative safety of torpor longer, emerging later in spring when there are more resources to support them.

Press reports of 'wasp invasions' typically appear in late May and June but are usually premature. Plus, a native insect having a good year is hardly an invasion!

9,000 wasp species live in the UK. Of these, just nine are classed as social

PHOTO: PAVEL KRASENSKY/NATUREPHOTO, JELGER HERDER/FLPA

ALIEN INVASION

Mild winters could mean that colonies start surviving the colder months, continuing to grow and building massive nests. This is already a problem in New Zealand and Australia, which both suffer from introduced wasp species. Meanwhile, climate change could lead to new species reaching the UK. British beekeepers are already on the lookout for the Asian predatory wasp; this bee-killing hornet recently arrived in France from Asia.

WHICH WASP?

The largest social wasp in the UK is the distinctive European hornet. The most likely species one will encounter is the common wasp (pictured right), but the median wasp, the tree wasp, the Saxon wasp, the German wasp and the red wasp can also be frequently encountered in some areas.

BBQ BLIGHTER

It is the worker wasps that we see out and about in the summer, looking for food. Common wasps feed their larvae on insects, which the workers bring to the nest. The adults consume nectar, ripe fruit and other sugary foods – including jam sandwiches and fizzy drinks.

Large mandibles allow the wasps to strip wood and rip apart their prey

The yellow and black colouring deters potential predators

The sting is a modified ovipositor, which is an egg-laying organ that's only present in females. Unlike honeybees, wasps do not die after they sting you

90kg

was the weight of a two-year-old German wasp nest found in Tasmania in April 2015

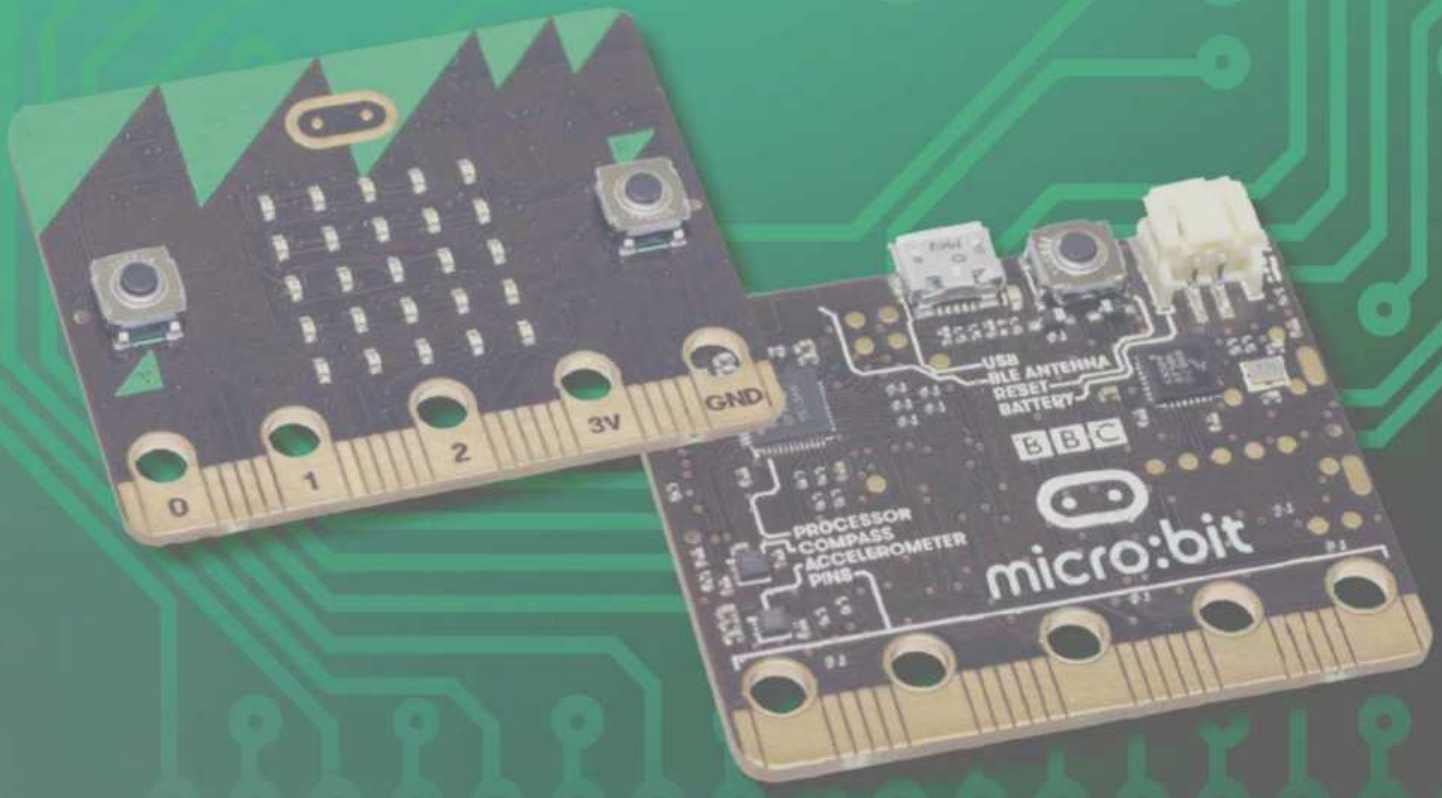
WHY WE NEED WASPS

Wasps are predators that control plant pests and enhance biodiversity by preventing common species becoming dominant. One worker wasp can collect over 100 aphids a day, while some wasps will pollinate flowers. They are a vital part of the ecosystem. Social wasps demand our attention, and sometimes not always for the best reasons, but they also deserve our interest and our respect.

PROF ADAM HART lectures in ecology and animal behaviour at the University of Gloucestershire

THE FUTURE OF GADGETS
TECHHUB

EDITED BY **RUSSELL DEEKS**



ON THE HORIZON

MICRO MACHINE

A tiny new computer aims to kick-start Generation Code

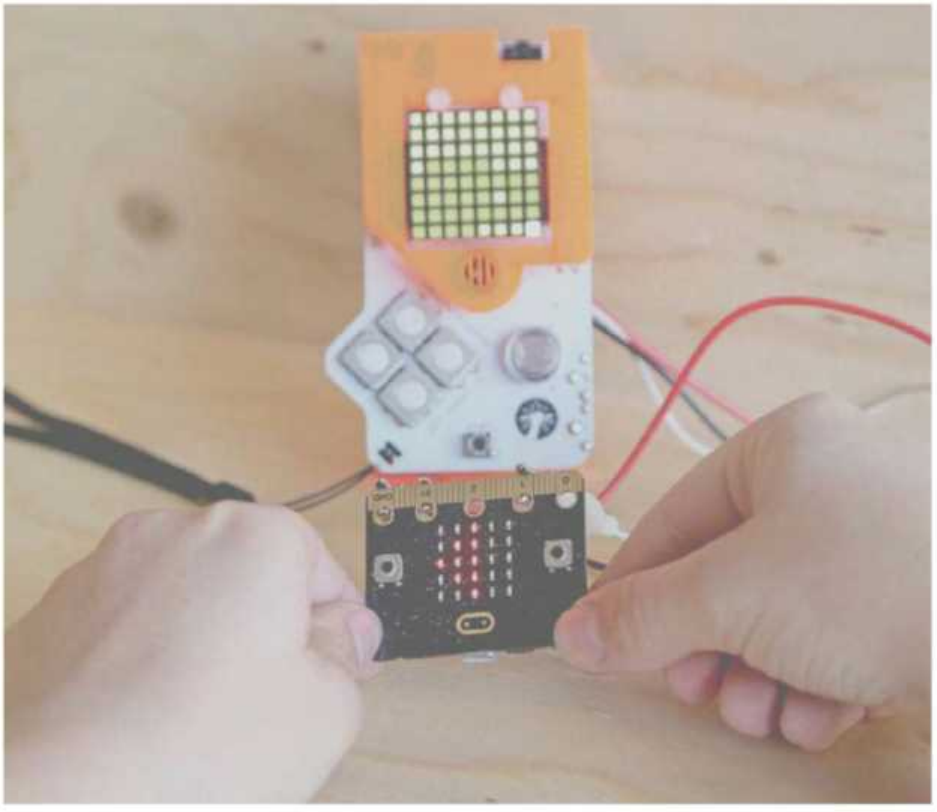
techwillsaveus.com/microbit

Back in 1981, the BBC and Acorn omputing launched the BBC Micro, a microcomputer that was sold to UK schools at subsidised prices. Along with the Commodore 64 and ZX Spectrum, the soon-ubiquitous BBC Micro helped inspire a generation, leading to the growth of a thriving British computer games and software industry. "The Beeb introduced a generation of British children to the power of programming," Wolfram Research's Conrad Wolfram said in 2011, while Codemasters co-founder David Darling described it as "central to the whole [8-bit] revolution".

Now, 34 years on, the BBC is looking to repeat the trick again with the BBC micro:bit. This Raspberry Pi-like device will be given to every Year 7 student (11- and 12-year-olds) this October, with the aim to get an entire generation interested in computer coding.

"We happily give children paintbrushes when they're young, with no experience. It should be the same with technology," states Sinead Rocks, Head of BBC Learning, which is the division that masterminded the project. "The BBC micro:bit is all about young people learning to express themselves digitally."

The BBC micro:bit has been created with the assistance of 29 industry partners, including the likes of Microsoft,



The BBC micro:bit is a pocket-sized computer that can be hooked up to other devices

Samsung and the Wellcome Trust, and aims to address a concern often voiced by employers: namely, that current IT teaching produces school-leavers who know how to use computers, but have very little idea how they actually work. Accordingly, the micro:bit has been designed as a 'blank canvas', a tool that budding engineers can use to build whatever they want.

It's essentially a printed circuit board that measures 5cm by 4cm and weighs 8g. Mounted on the board are 25 red LEDs in a 5x5 matrix, two programmable buttons, a three-axis accelerometer, a compass, a Bluetooth chip, three connectors that will accept crocodile clips or banana plugs, a 20-pin edge connector and a micro-USB controller. It can connect to a wide range of sensors, and to other similar devices such as the Raspberry Pi or the Arduino One. Early prototypes also featured a slot for a watch battery, but this has since been removed for safety reasons; anyone wishing to use the micro:bit to create a wearable device will need to add a AAA battery pack.

That's the hardware side of things. The micro:bit also comes with its own web-based, multi-platform editing and programming environment. Using a desktop computer, tablet or smartphone, users can write programs for the micro:bit in any of several languages, including C++, Javascript, Python and Blocks. They can then upload them to the micro:bit server, which will send back compiled code that the user simply drags and drops to their micro:bit.

A large number of uses for the micro:bit have already been suggested, including using it as a controller for a DVD player, building a metal detector or spirit level or, for the more ambitious, making it the heart of an Internet of Things-connected device. Indeed, the latter seems to be something of a mission objective, with Rocks saying, "As the micro:bit is able to connect to everything from mobile phones to plant pots and Raspberry Pis, this could be for the Internet of Things what the BBC Micro was to the British gaming industry."

With one of these devices about to be put in the hands of youngsters across the nation, who knows what uses they'll come up with for them? And if you're not aged 11 or 12, there's no need to feel left out – a consumer model of the micro:bit is set to go on sale in various outlets before the end of the year. ■

RUSSELL DEEKS is a freelance science and technology journalist

TECHOMETER

WHAT'S HOT

RETRO GAMING

Commodore is about to launch a smartphone. Named PET after the company's original game-changing computer, the Android device will have emulators that let you play old C64 and Amiga games. Spectrum fans, meanwhile, will soon be able to get their hands on the ZX Vega, an emulator with 1,000 vintage games built in.

WHAT'S NOT

AIBO

Sony's robot dog caused a sensation when it launched back in 1999. But Sony cancelled the line in 2006, and announced last summer it would no longer be repairing them – with the result that some Buddhist priests in Japan are now offering AIBO cremations so that distraught owners can see their robotic loved ones off in style.

READER POLL

Which would you prefer your child to learn?

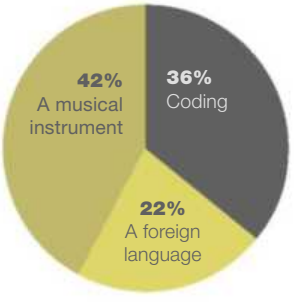


PHOTO: TECHNOLOGY WILL SAVE US

THE NEXT BIG THING

TOTAL IMMERSION

Cinemas that use virtual reality could offer a truly immersive experience

Previously, I was the online editor for the Cambridge Film Festival. I'm still a big fan of watching a great film in a fine cinema with an engaged audience – dark rooms with good sound systems are a fabulous forum for shared experiences. But just when cinema looked like it had managed to cope with the advent of television and the growth of smaller and more portable screens, it has to cope with the next big thing – immersive video.

The rapid development of augmented/virtual reality headsets is changing the rules. They offer new ways to tell stories, along with a compelling experience that could challenge cinema viewing.

Virtual reality headsets have been around for a while. Oculus Rift, one of the main developers, is now owned by Facebook, while Microsoft has announced its HoloLens system. Samsung Gear VR uses a smartphone as its display, and Google has developed Google Cardboard, which can turn your smartphone into a passable VR viewer.

Earlier this year, the award for the best interactive documentary at Sheffield Doc/Fest, one of the major documentary film festivals in the world, went to Clouds Over Sidra. This short immersive film about the life of a 12-year-old girl was filmed in a refugee camp near the Syrian border. This documentary would have been interesting enough on a TV screen, but it became truly compelling when you could turn your head to see the camp stretching to the horizon, or the baker making cakes on the range in the corner of the tent.

The BBC is already experimenting with the 360o format for news reports. The emotional impact can be immense – the effect of seeing a bomb attack in Nonny de la Peña's Project Syria is far greater than watching it on TV. However, the new technology is very different from using a single camera and it will require new ways of working, new ethical frameworks and simpler tools for capturing and editing. One important issue is where to put the crew – when filming with 360° the viewer can see where your sound man is standing!

At the moment the experience is an individual one, with each of us seeing the scene on our own. But Microsoft has already worked with NASA to link together users of its HoloLens system so they can work collaboratively on images of the Martian surface. Meanwhile, innovative developers are working on ways to use headsets to provide a communal experience somewhere between cinema and actually being there.

We are starting to see what cyberspace might really look like, and it's pretty exciting. Of course, I'm really waiting for us to start connecting our visual systems to our computers without the clumsy screens getting in the way, but that's not going to happen just yet.

BILL THOMPSON
contributes to news.bbc.co.uk and the BBC World Service

FROM THE LAB

Smart headlights that read the road

WHAT IS IT?

Ford's Camera-Based Advanced Front Lighting System is being developed at the car maker's Research & Innovation Centre in Aachen, Germany. The manufacturer's system builds upon current 'smart' features to produce headlights that can self-adjust, enhancing the headlights when approaching hazards such as animals in the road, bends or junctions.

HOW DOES IT WORK?

An infrared camera in the car's front grille detects body heat from people or animals up to 120m away, then two independent spotlights illuminate them. The system also incorporates GPS, which monitors your whereabouts and boosts your headlights at blind bends or junctions. When there's no GPS signal, the camera can track road markings by 'reading' traffic signs.

WHEN WILL IT BE IN ACTUAL CARS?

Ford says that "we expect this technology to be available for customers in the near term", but has not given any definite timeline as yet. For those readers who are not au fait with motor vehicle industry terminology, "the near term" is around the same length as a piece of string… so we'll just have to keep our eyes peeled.

A display in the car outlines hazards in either yellow or red, depending on the level of risk

PHOTO: GOGORO

Q&A

YOUR QUESTIONS ANSWERED

BY OUR EXPERT PANEL

SUSAN BLACKMORE
Susan is a visiting psychology professor at the University of Plymouth. Her books include *The Meme Machine*

DR ALASTAIR GUNN
Alastair is a radio astronomer at the Jodrell Bank Centre for Astrophysics at the University of Manchester

ROBERT MATTHEWS
After studying physics at Oxford, Robert became a science writer. He's a visiting reader in science at Aston University

GARETH MITCHELL
Starting out as a broadcast engineer, Gareth now writes and presents *Digital Planet* on the BBC World Service

LUIS VILLAZON
Luis has a BSc in computing and an MSc in zoology from Oxford. His works include *How Cows Reach The Ground*

editorial-bbcknowledge@regentmedia.sg

Q

What happens to old aeroplanes?

A Many end up in so called 'boneyards' like that at Victorville in California (pictured). Located at the edge of the Mojave Desert, the arid environment is ideal for storing aircraft as there is little risk of corrosion. The Victorville facility is based at Southern California Logistics Airport and has 500 parking spaces for old planes.

The boneyards of the world are increasingly filling with Boeing 747s; these jumbo jets are gradually being replaced by newer planes such as the Airbus A350 and the Boeing 787, which are capable of flying longer hauls more efficiently. Increasingly, super jumbos are only required on routes across remote regions with fewer airfields. In this situation, four engines are a safer option.

Boeing is currently scaling production back to just one 747-800 model each month. If that reflects a wider decline in demand for big planes, then the Victorville facility had better free up plenty more parking spaces in its famous boneyard for the iconic beasts of the sky. **GM**

The planes patiently waited to be loved once again

PHOTO: JIM OLIVE/POLARIS/EYEVINE

Q&A

In Numbers

US$100m

has been contributed to the search for extraterrestrial intelligence by Russian billionaire Yuri Milner

Why are some people left-handed?

A One simple answer is that handedness runs in families and is inherited. Scientists have recently found a network of genes that is responsible for body asymmetry and also influences handedness. The deeper question is why about 90 per cent of people are right-handed and only 10 per cent left-handed. In other species that show a hand (or paw) preference, including chimpanzees, polar bears, dogs and cats, the split is about equal. One theory relates handedness to language, because most people's language centres are in the left hemisphere. Another is that in a mainly right-handed culture, being left-handed might give a small advantage in outwitting an opponent. This may explain the success of many left-handers at the top level in such sports as fencing, tennis and cricket. Working against this is the value of cooperation, which is easier when everyone is right-handed. So these combined pressures might explain the stable 90:10 split. **SB**

A single-celled Xenophyophore measuring 20cm in width, located in the Atlantic Ocean

What animals live at the bottom of the Mariana Trench?

A When Don Walsh and Jacques Piccard made the first expedition to the bottom in 1960, they reported seeing a flatfish but they didn't take photographs. Other marine biologists now think this was probably a sea cucumber. No other survey has found fish deeper than 8,145m and the Mariana Trench reaches down to almost 11km. But it's not devoid of life. There are shrimp-like amphipods – a type of crustacean – the size of rabbits living there, as well saucer-sized animals called Xenophyophores. These look a lot like coral but are actually a single cell with multiple nuclei. They feed like an amoeba, by engulfing particles of ocean debris. **LV**

Do plants really grow better if they 'hear' human voices or music?

A There is some evidence that they might. A 2014 study at Osmania University in Hyderabad, India found that roses grew faster when exposed to Indian classical music than Western rock music or silence. And a 2011 study at Zhejiang University in China reported 10 per cent faster mushroom growth when the fungi enjoyed a mixture of music and cricket chirps. Sound vibrations have also been shown to activate certain plant genes. But in these studies the researchers could hear the music too, so it may be that people do a better job of tending plants when they listen to music they like. **LV**

PHOTO: NOAA, ISTOCK X2, ALAMY, SCIENCE PHOTO LIBRARY, GETTY

A typical visualisation of the the main asteroid belt. But in reality, large asteroids are much more spread out

Q

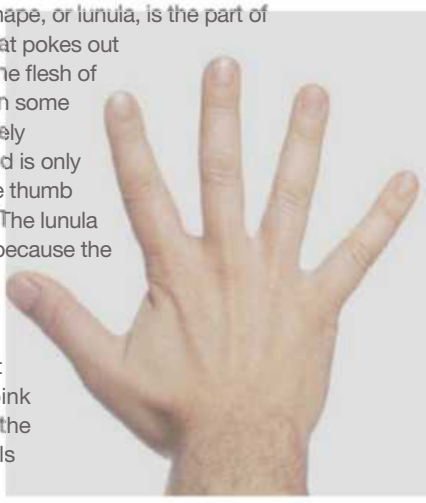
How do spacecraft avoid hitting asteroids and meteoroids?

A They don't! The main asteroid belt is actually much less populated than is often depicted in the movies. It has a volume of about 50 trillion trillion cubic kilometres (which would take about 35 million Suns to fill!). Astronomers estimate the number of asteroids bigger than about 1km in size in the main asteroid belt is about 80,000. This means that, on average, the distance between large asteroids is about 17 million kilometres. Even if we include estimates for the number of smaller asteroids in the main belt, we still find that the average distance between asteroids is millions of times the size of a typical spacecraft. Outside the main asteroid belt, the average distance between potentially hazardous objects is millions of times greater still. So, the chances of an accidental collision between a spacecraft and an asteroid are actually extremely small. Hence, mission planners don't need to take any special steps to avoid asteroids and meteoroids. **AG**

Q

What are the white semi-circles at the bottom of our nails?

A Your nails are made from keratin secreted by a layer of living tissue at the base of the fingernail called the nail matrix. The moon shape, or lunula, is the part of the matrix that pokes out from under the flesh of your finger. In some people it barely protrudes and is only visible on the thumb and big toe. The lunula looks white because the epidermis is thicker beneath the matrix and it blocks the pink colour from the blood vessels below. **LV**



Q

Why doesn't a Cadbury Flake melt in the microwave?

A Although Flake is made from milk chocolate, the manufacturing process gives it a different arrangement of fat and cocoa solids, so the melting fat isn't able to lubricate the cocoa particles to the point where they can flow. In a bain-marie, a Flake will never melt. In the microwave, it eventually just burns. **LV**

Ruining a Cadbury Flake is a pretty heinous crime

Q&A

TOP TEN
FASTEST STEEL ROLLER COASTERS

1. Formula Rossa
Location: Ferrari World, United Arab Emirates
Speed: 240km/h (149mph)

2. Kingda Ka
Location: Six Flags Great Adventure, USA
Speed: 206km/h (128mph)

3. Top Thrill Dragster
Location: Cedar Point, USA
Speed: 190km/h (118mph)

4. Dodonpa
Location: Fuji-Q Highland, Japan
Speed: 172km/h (107mph)

5. Superman: Escape From Krypton
Location: Six Flags Magic Mountain, USA
Speed: 167km/h (104mph)

6. Tower Of Terror
Location: Dreamworld, Australia
Speed: 160km/h (99mph)

7= Steel Dragon 2000
Location: Nagashima Spa Land, Japan
Speed: 153km/h (95mph)

7= Fury 325
Location: Carowinds, USA
Speed: 153km/h (95mph)

9. Millennium Force
Location: Cedar Point, USA
Speed: 150km/h (93mph)

10. Leviathan
Location: Canada's Wonderland, Canada
Speed: 148km/h (92mph)

PHOTO: JOE BAZ/STEVE NUSS/SARAH ACKERMAN/RUSSELL HEIMAN/CHARINA DUENAS/PERIPHERALPROTON/HOLIDAY POINT/BEASTER725/ANDREW HITCHCOCK/FLICKR, JORDAN MESSANGER/WIKI, GETTY X4, SCIENCE PHOTO LIBRARY

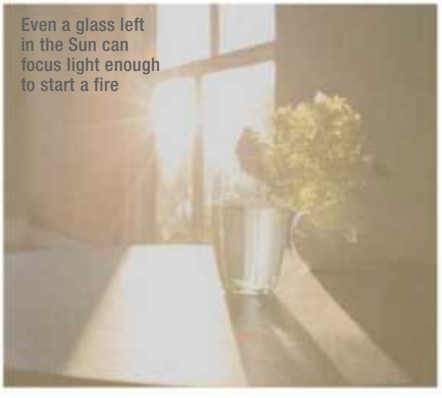
How does light travel down a fibre optic cable?

Fibre optics can be used to transmit light and telecommunications

A At the core of the cable is a strand of plastic or pure optical glass about 0.01mm in diameter. Surrounding it is a highly reflective cladding with a different refractive index to that of the core. The refractive indices of each material are engineered to ensure that light always reflects back off the cladding and is never absorbed by it, regardless of whether the cable is straight or bent round. It's a bit like carrying a torch through a long winding tunnel lined with perfect mirrors. **GM**

Can the Sun shining through glass really cause house fires?

A It may sound like an urban myth, but it can and does happen. Fish tanks, jam jars and even glass door knobs have been implicated in focusing the Sun's rays sufficiently to cause smouldering, followed by a full-scale blaze. Earlier this year, London Fire Brigade said that 125 fires have been triggered by the Sun's rays over the last five years – and warned that the risk exists during the winter as well as summer. That's because the Sun's rays bathe the Earth in a constant flow of thermal energy spread over each square metre. This energy is too dilute to ignite paper, wood or other combustible substances, but if the rays are focused, it becomes concentrated enough to exceed the threshold for combustion. Magnifying glasses do this very effectively, refracting the rays and bringing them to a tight focus. But even fragments of glass can have some focusing effect – with potentially disastrous consequences. **RM**



Even a glass left in the Sun can focus light enough to start a fire

Can a planet's atmosphere get bigger over time?

The volume or thickness of a planet's atmosphere depends on its temperature, its composition and the planet's escape velocity. The escape velocity depends only on the mass of the planet. Although planet masses can change, these changes are so tiny compared to the total mass of the planet that the escape velocity remains essentially constant.

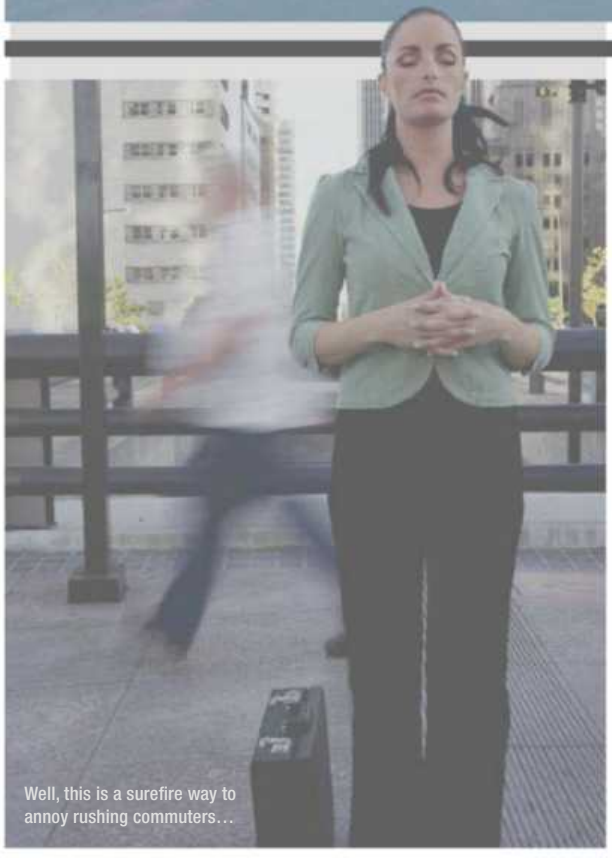
The temperature of planetary atmospheres can change significantly due to changes in solar irradiance, and higher average temperatures would result in a larger atmosphere. Composition changes, which can occur due to geological processes or the transference of gases in and out of the atmosphere, also affect the size of the atmosphere. A smaller average mass of the atmosphere's constituents would result in a larger atmosphere. So, planetary atmospheres can become larger (or smaller) over long timescales due to environmental, geological and biological processes. **AG**

Did you know?

Cracker butterflies are the noisiest butterflies in the world. Their cracking forewings can be heard from 30m away

Why does heat make roads appear wet in the distance?

On hot days, air just above the road can become hotter and less dense than air higher up. The optical properties of this 'inversion layer' can lead to light rays from the sky – that would otherwise hit the road – curving upwards. This creates the illusion that they have bounced off a pool of water on the road. **RM**



Well, this is a surefire way to annoy rushing commuters…

Is mindfulness good for you?

Generally, yes, but not always and not for everyone. Derived from Buddhist teachings, mindfulness means paying steady attention to the present moment without letting your mind wander into fantasies, fears or planning. You can practise mindfulness in meditation or in the midst of ordinary life. The Mindfulness-Based Stress Reduction programme claims to decrease anxiety and depression, and increase concentration and wellbeing, with remarkable results reported from prisons, schools, homes and workplaces. Yet many experiments lack proper control groups and few have looked seriously at negative effects. Being mindful is extremely hard at first, because trying to clear your mind means facing up to all those unwanted thoughts and fears. This can be painful and disturbing, so some people feel a lot worse before finding the benefits of self-knowledge and a calmer mind. Stress hormones can increase even when people say they feel more relaxed, and psychiatrists have warned of troubling side-effects including a changing sense of self, depersonalisation, and floods of traumatic memories. A good mindfulness teacher can make all the difference. **SB**

Q&A

Air quality is a problem in China, but pollution is rising at a slower rate than during the Industrial Revolution

With the current rate of pollution, when will the Earth become uninhabitable for humans?

A It won't. Humans are not like yeast, which continues to metabolise in an uncontrolled manner until it is poisoned by its own waste products. As human pollution levels rise, the political imperative for us to do something about it increases as well. The Great Smog of London in 1952, which killed 4,000 people, was followed four years later by the Clean Air Act. Similar legislation in the US has seen the overall emissions of air pollutants fall by about 60 per cent in the last 35 years. The US 1990 Oil Pollution Act required oil tankers to have double hulls to reduce the risk of spills. The 1987 Montreal Protocol eliminated almost all CFCs from industrial and consumer products worldwide. Leaded petrol and the pesticide DDT are also banned in most places. Air and water pollution are still a major problem in newly industrialised regions, particularly China, India and South America. But even then, pollution is rising more slowly than when the West went through the Industrial Revolution. This is because of better awareness and technology, as well as pressure from the rest of the world.

Global population is expected to peak around 10 or 11 billion. With care, it's possible that we may be able to sustain a habitable planet for that many humans more or less indefinitely. We may still become extinct through climate change, disease, nuclear war or meteorite impact, but humanity probably has enough foresight and resources to avoid poisoning itself to death. **LV**

Why don't doctors adjust for age and size when prescribing drugs?

A They do, though exactly how depends on both the patient and the medicine. For example, elderly patients often have liver and kidney function issues, which reduces the dose they can tolerate. In contrast, babies and toddlers are so small that their response to drugs depends critically on their weight, sometimes unpredictably. Even the gender of the patient can play a role in deciding dose. Then there's the type of drug: some are fat-soluble, so the correct dosage depends on Body Mass Index (BMI) – that is, total weight divided by the square of height – while other drugs are water-soluble, where dosage is better based on lean body mass. Yet another complication comes from the so-called therapeutic index of a drug – roughly speaking, how big a dose can be given before benefit turns into toxicity. Calculating the right dosage then depends on striking a balance between giving a high enough dose to tackle the condition, but not so high that it does more harm than good. According to Prof Donald Singer of the British Pharmacological Society, this is often the case with cancer therapy and some powerful antibiotics, and getting the dosage right for a specific patient can be very challenging. **RM**

PHOTO: GETTY ILLUSTRATOR: ACUTE GRAPHICS

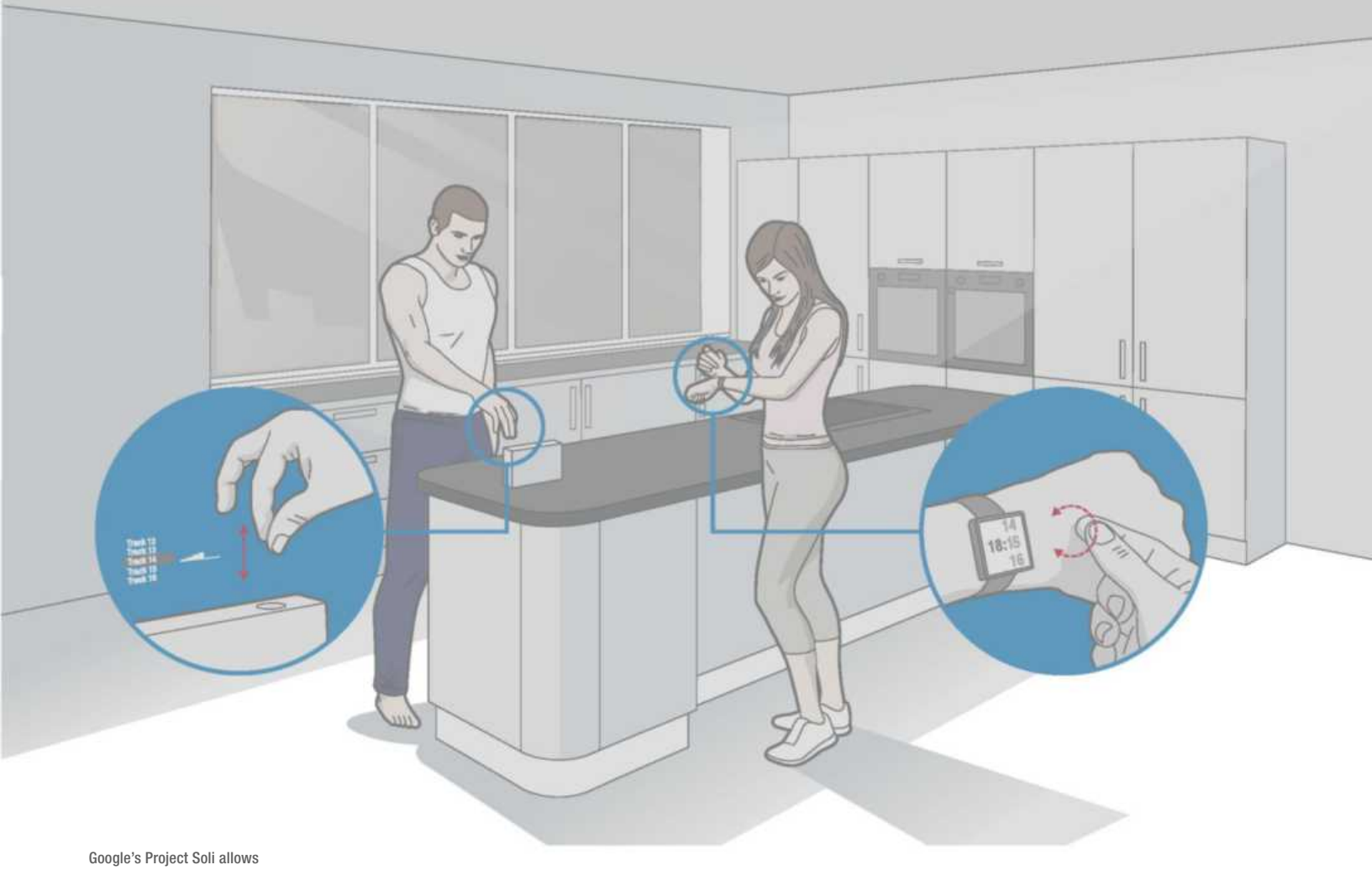
PROJECT SOLI

Google's Advanced Technology and Projects (ATAP) division specialises in creating futuristic technology, such as interactive clothing and an open source modular smartphone platform. One of its most recent prototypes, Project Soli, allows the control of electronic devices without touch. So instead of stabbing away at your tablet or smartphone with your chubby mitts, you make elegant hand movements in mid-air that are translated into commands. Want to turn up the volume? Just twiddle your fingers. Need to turn a page? Simply swipe your hand.

Project Soli has taken shoebox-sized radar hardware and has shrunk it right down so that it can be embedded on a chip. German manufacturer Infineon is working with Project Soli to develop the chips.

The radar transmits a wave towards a target, such as your hand. The radar receiver then intercepts the energy that reflects back. A lot of information can be interpreted from one radar signal because of the gesture recognition system that has been built by Project Soli. Unlike camera-based systems from companies like Leap Motion, Soli needs no additional hardware and its radar signals are capable of penetrating other materials. This means that even if the chips are embedded inside objects, they can still accurately detect hand gestures. The sensors are incredibly accurate and capable of capturing motion at 10,000 frames per second from as far as a metre away. As the device is so small, it can be incorporated into a range of electronic gadgets and wearables.

Google's Project Soli is ready for mass production and will be released to developers later in 2015.



Google's Project Soli allows gadgets and wearables to be controlled with hand gestures

Q&A

Why are some people always so angry?

A Medical reasons include a hyperactive thyroid, diabetes, cardiovascular disease and dementia. Healthy people may resort to anger because they cannot deal with fear, disappointment, frustration or embarrassment. They want to control the world and cannot, or they feel a failure or worthless and blame others for everything that goes wrong. All of this may have roots in past trauma or in poor parenting that leaves children ill-equipped to understand and cope with their own and others' varying emotional states. Anger often harms the angry person more than anyone else. There's no quick fix, but a good start is to recognise your own anger and establish what triggers it as soon as it begins. **SB**

In Numbers

15.72m

is the length of the largest walking robot in the world. It is designed to look like a dragon and can even breathe fire!

How does a small bird such as a robin produce such a loud sound?

"Hey you, get off my tree!"

A Male birds use their songs to advertise for mates and to warn rival males away from the territory they control. Natural selection favours birds that can broadcast over a wider area and so they have evolved powerful diaphragm muscles. But they use other strategies to make themselves heard as well. Research at the University of St Andrews has found that as traffic gets louder, birds sing at higher frequencies, which aren't affected so much by the low rumble of passing lorries. And robins in cities sing more at night time too, to avoid the rush hour noise. **LV**

What happens if you fire a gun in space?

A Assuming you are floating freely in space, the gun will work just as it does on Earth. Modern ammo contains an oxidising agent to trigger the explosion, so a gun will still fire, despite the lack of oxygen. However, the bullet will continue moving for thousands of years, eventually coming to a stop due to the friction from the diffuse material found in 'empty' space (or when it encounters another object). You will also begin to move, in the opposite direction to the bullet, at a velocity of several centimetres per second. **AG**

That's one way of getting around

PHOTO: GETTY X4, SCIENCE PHOTO LIBRARY, ISTOCK X2

Could alien life breathe a gas other than oxygen?

A Free oxygen is so reactive that it doesn't last long in the atmosphere unless it is continuously replenished by plants and other photosynthetic organisms. This means that on any planet, including Earth, life must initially evolve without any oxygen to breathe. There are lots of modern bacteria species that 'breathe' other elements and compounds, including sulphur, carbon dioxide, iron, manganese, cobalt and uranium. All of these substances are much less common in the Universe than oxygen, which is the third most common element. There are bacteria that can metabolise hydrogen gas, which is the most abundant element, but like all of these alternative metabolisms, it is much less efficient than oxygen-based systems. This might mean that simple bacterial life that uses lots of different biochemical techniques is common across the Galaxy, but complex multicellular life only evolves where it has access to the boost in energy provided by oxygen reactions. **LV**

What are the small bubbles that form in a glass of water?

A Water contains dissolved gases. When a glass of water is left to stand, the molecules come out of solution and accumulate around small imperfections on the glass. This process of 'nucleation' continues until a bubble forms, breaks free and rises to the surface. Dropping a lemon pip into fizzy water can trigger repeated cycles of nucleation and bubble formation, making it rise and fall repeatedly. **RM**

Could a dinosaur survive in today's climate conditions?

A It's doubtful. Despite what Jurassic Park would have you believe, Tyrannosaurus rex and Triceratops lived in the Cretaceous Period. This ended 66 million years ago. The average global temperature at the time was about 4°C higher than today, with much less difference between the temperature at the Equator and the poles. The sea temperature averaged 37°C, so even tropical seas today would be too cold for marine life of the time. But land dinosaurs would be quite comfortable with the climate of tropical and semi-tropical parts of the world today. That is, until they all died of altitude sickness. Studies of air bubbles trapped in amber show that the atmosphere of the Cretaceous may have had up to 35 per cent oxygen, compared to today's 21 per cent. For T. rex, this would feel like being at the base camp of Everest. In such thin air, dinosaurs would be too breathless to chase hapless tourists. **LV**

Q&A

THE SCIENCE OF SOGGY BOTTOMS

Q&A SPECIAL

***If* you understand the chemistry behind your cakes, you'll have perfect results every time**

What happens when cream is whipped?

A Cream contains water, milk sugars, a small amount of protein and lots of fat. When cream is whipped, small air bubbles become trapped in the mixture. Meanwhile, the fat, which exists as fairly stable droplets inside a cream carton, begins to break up when whizzed around with a whisk. As the fat droplets break apart, molecules of fat rearrange themselves around the air bubbles.

As the air can't escape from the fat, the cream starts to increase in volume until it becomes stiff enough to spread over cakes and pies.

TIP: You should stop whipping cream when it forms stiff peaks – if you carry on, the fat breaks up even further, the air bubbles collapse, and you're on the way to making butter.

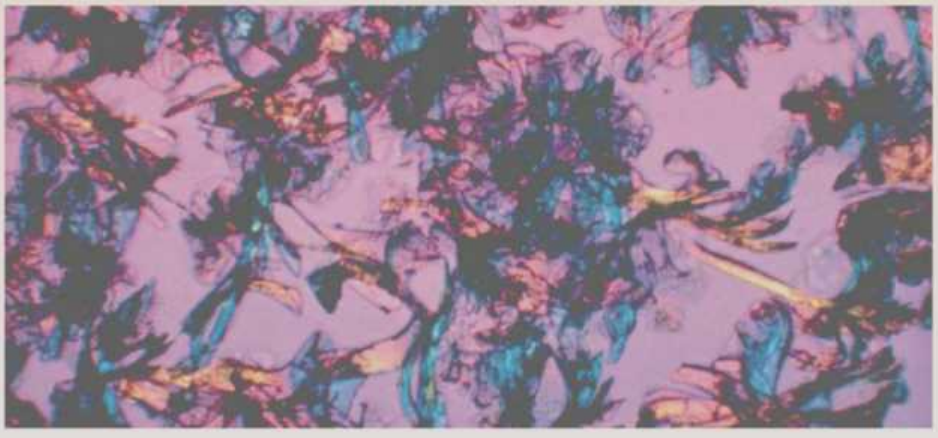
Why do biscuits go soft?

Unlike bread and cakes, which tend to become hard the longer they spend in the air, most biscuits go soft. Biscuits are baked to have a low moisture content, which gives them their crunchy texture. When biscuits aren't quickly scoffed, they start to absorb moisture from the air, making them go soft.

TIP: Biscuits should be kept in a dry environment to reduce the amount of water absorbed.

Does chocolate make you happy?

A 1996 study showed that chocolate caused the release of endorphins in the brains of American women, making them feel happy. Chocolate contains a number of compounds associated with mood-lifting chemicals in the brain. Frequently mentioned are phenylethylamine, a natural antidepressant, and tryptophan, which is linked to the production of serotonin – a neurotransmitter associated with happiness. A handful of other substances also add to chocolate's purported effects. Theobromine can increase heart rate, and caffeine is known as a 'wake-up' drug. But most of these compounds are present only in tiny quantities in chocolate, and some scientists say that they are probably almost entirely digested before they reach the brain. It may instead be the experience of eating chocolate, and satisfying a food craving, that releases endorphins and 'happy feelings' more than the content of the chocolate itself.



Tryptophan is an amino acid that's linked to serotonin production

Can baking improve your mental health?

John Whaite, winner of 2012's The Great British Bake Off, published a recipe book explaining how baking helped him cope with depression. Creativity, goal-orientated behaviour and focused attention are all central to baking, and are associated with positivity and a sense of accomplishment. Other potential benefits come from engaging less-used senses – particularly touch, taste and smell – and from the rewarding feeling of making something that can be shared.

However, most of the evidence for the link with mental health is anecdotal. A small 2004 study in the British Journal Of Occupational Therapy suggested that baking classes boosted confidence in a group of inpatients in mental health clinics, but more research still needs to be carried out.

Heaviest slab of fudge

Record: 2.61 tonnes
Location: Levack, Ontario, Canada
Year: 2010
Notes: The fudge took one week to make and was flavoured with vanilla, chocolate and maple

PHOTO: GETTY, ALAMY, CAMERA PRESS, NOTHWEST FUDGE FACTORY, SCIENCE PHOTO LIBRARY

Flimsy baking equipment can lead to soggy pastry

Why do pies get a soggy bottom?

A The main ingredients in pastry are flour and fat. The gluten in the flour gives pastry its texture, while fat offers flavour. If the fat melts before a strong gluten structure has formed, the pastry will end up soggy. Overly moist fillings can also contribute to a soggy bottom as the liquid will drop to the bottom of the pie and ooze into the pastry. To ensure crisp pastry, the base can be blind baked before adding the filling. Alternatively, fillings should be cooled before adding to the pastry to cut down on the amount of steam, and therefore moisture, that's produced. Cutting large slits into the lid of the pie ensures that steam can escape.

TIP: Sturdy, good-quality tins heat faster than flimsy ones and retain higher temperatures, which keeps pastry crisp.

To keep apples looking fresh, damage their enzymes

Why do apples turn brown so quickly?

A When you slice into an apple, air reaches the inner part of the fruit. Once exposed to oxygen, enzymes in the apple begin converting natural chemicals called polyphenols into brown melanin compounds. This year, the US government approved a genetically modified apple variety that can't produce the browning enzyme. They can be sliced and diced without losing their fresh appearance.

TIP: To prevent browning, place apple slices under water to starve the enzyme of oxygen, or damage the enzyme by adding lemon juice to the cut surface.

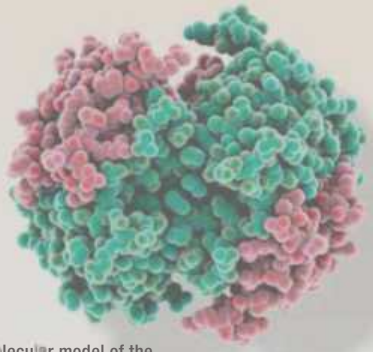
Oldest cake

Record: 117 years old
Year: 1898
Location: Willis Museum, Basingstoke
Notes: It has a large crack due to a WWII bomb blast. It has recently been treated with silicon gel to increase its lifespan

What gives meringue its unique structure?

A Meringue contains egg white, which is a mixture of proteins and water. Air whisked into the egg white becomes trapped and surrounded by a network of proteins. Adding sugar after the eggs have been whisked stabilises this protein network. When the meringue is cooked, water in the egg white evaporates, the air bubbles expand and the protein network is solidified, forming a light, crisp structure.

TIP: Meringue mustn't be cooked too quickly or at a high heat, because if the sugar cooks before the water has had time to evaporate, you'll end up with a brown meringue with a soggy middle.



Molecular model of the protein in egg white

PHOTO: GETTY, ALAMY, PHOTOSHOT, SCIENCE PHOTO LIBRARY, MARK AUTY/TEAGASC
PAUL CARTER/HAMPSHIRE CULTURAL TRUST/HAMPSHIRE COUNTY COUNCIL

Q

Why does bread go stale?

A Staling is often attributed to a loss of moisture from bread. But on a microscopic scale, there's a lot more going on. The flour used to make bread contains high quantities of starch molecules. In their natural state, these form a crystalline, highly organised structure. Adding water to the flour undoes this structure, allowing the starch molecules to take on a more disorganised, gel-like arrangement that gives bread a soft, fluffy texture when it comes out of the oven. As bread starts to cool, water leaves the starch and moves into other parts of the mixture, allowing starch molecules to return to their crystallised state. It's this recrystallisation – not drying – that makes bread go hard, and it happens even in humid conditions. Keeping bread in the fridge doesn't help. In fact, recrystallisation happens faster at cooler temperatures. Freezing, however, dramatically slows the process, which is why bread can be successfully stored in a freezer.

Longest baguette

Record: 111m
Year: 2009
Location: Ho Chi Minh City, Vietnam
Notes: The baguette was cooked in a 120m oven and took 11 minutes to bake

This image of bread was taken using a microscope and shows starch (brown), fat (purple) and the gluten network (red)

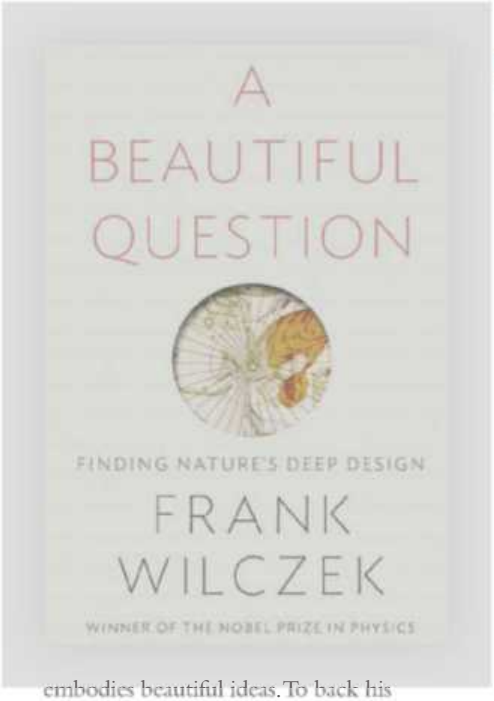
A Beautiful Question

Finding Nature's Deep Design

Frank Wilczek

Allen Lane (H)

Hardback (H) Paperback (P)



Does the world embody beautiful ideas? In these days of global turmoil and seemingly endless reports of misery, atrocity and death, a natural response would be: "Are you joking?"

Even if everything was just fine, such questions do come across as a bit academic. Sure enough, the author of A Beautiful Question is an academic. More surprising, perhaps, is the fact that Frank Wilczek is a professor of theoretical physics, whose practitioners are notorious for having little patience with airy-fairy philosophical issues.

But Wilczek is no ordinary physicist. In 1973, at the age of just 21, he and his doctoral advisor David Gross at Princeton University made a major discovery about how the Universe is put together. Roughly speaking, they showed that the nuclei of atoms are held together by a bizarre force that gets stronger with distance. In the process, they explained why quarks – the building blocks of matter – are trapped inside protons and neutrons, and won a share in 2004's Nobel Prize in Physics.

What Wilczek argues he really found, however, is evidence that the world (by which he means the entirety of creation) embodies beautiful ideas. To back his claim, he's pulled together his thoughts into what he calls "a long meditation" on the subject.

"It's rare that scientists as brilliant as Wilczek give us a glimpse of what goes on inside their heads"

And A Beautiful Question is just that: over 300 pages, plus a 60-page glossary, and artwork illustrating everything from Platonic solids to yin and yang.

This may all sound a bit hippy-dippy, and some readers may see parallels with two bestsellers from the 1970s, The Tao Of Physics by Fritjof Capra and The Dancing Wu Li Masters by Gary Zukav. Both claimed to have uncovered connections between quantum theory and New Age ideas about consciousness and the cosmos.

Be warned: Wilczek is no hippy. His exploration of parallels between concepts from art, like symmetry and projective geometry, and those from high-energy physics are sophisticated and, frankly, often pretty opaque. Even experts in relativity may never have twigged that, as Wilczek puts it, "gravitons are the avatars of general covariance".

It's rare that scientists as brilliant as Wilczek give us a glimpse of what goes on inside their heads. Anyone taking up this opportunity should expect to come away pretty dazzled.

ROBERT MATTHEWS is Visiting Reader in Science at Aston University, Birmingham

MEET THE AUTHOR

Frank Wilczek

Why did you decide to write a book about beauty?
The seed was planted several years ago when I was asked to give a lecture on 'quantum beauty' at Cambridge University. I was inclined to turn it down at first, because it seemed so outlandish. But I found the idea really growing on me – it brought me back to the kinds of philosophical questions I was obsessed with as a teenager. The lecture was very well-received, and I've discovered more and more that if you poke underneath the surface, beauty is a big part [of physics].

Beauty is very subjective, so how do you define it?
In common usage, beauty has many subjective elements – a lot of our perception of beauty has to do with the human body and things that are emotionally resonant. But there are certain forms of beauty that we find represented in the fundamental ways the world works. In particular, these are ideas about symmetry, colour, shape, and building complicated structures from a few simple elements.

So is there a lot of symmetry in the Universe?
Symmetry is what runs the world. In physics, the fundamental equations that govern the Universe – the Standard Model – allow enormous ranges of transformations without changing their consequences. That's what we mean by symmetry of equations. In the 20th Century, it became such a dominant theme that we started with symmetry and used that to guess the equations. That's really how we got the theories of both the strong and the weak [nuclear] interactions.

The Scientific Secrets Of Doctor Who

Simon Guerrier and Dr Marek Kukula

BBC Books

The primary reason behind the phenomenal success of Doctor Who is good writing. Simon Guerrier and Marek Kukula's splendid volume illustrates this fact admirably by splicing together a collection of new Doctor Who short stories with their own supplementary chapters reflecting the current scientific thought behind each tale's themes – the 'sci' that underpins the 'fi', if you like. The book is divided into 'Space', 'Time' and 'Humanity' sections, which pretty much has all bases covered.

One of the joys of The Scientific Secrets Of Doctor Who is that you can dip in and out like a Time Lord skipping through time and space. Throughout, there's also a good smattering of facts about the show itself. It's an excellent blend of popular science and popular culture, it's cleverly structured, and is a great example of how science and fiction ultimately spring from the same creative well. It's an obvious no-brainer for hardcore Whovians, a no-brainer for anyone wondering what all the fuss is about, and a good 'beside the bed' book for people who are, like me, loitering somewhere in the middle.

■■■■■

DALLAS CAMPBELL is BBC presenter who recently fronted Britain Beneath Your Feet

Why Information Grows

The Evolution Of Order, From Atoms To Economies

Cesar Hidalgo

Allen Lane

Here, Cesar Hidalgo from MIT teaches us to view economies through the lens of information theory. He starts by explaining what information really is and goes on to explain how so much of it can exist in perfect order, despite the march of entropy pulling everything in the Universe towards disorder.

Throughout the book he introduces and explores many interesting and convincing concepts and arguments. Among them are 'the product space', a network used to examine how different products are related to one another within an economy, and the 'personbyte', the hypothetical maximum amount of knowledge that one individual can possess. These concepts highlight the importance of large networks of individuals in performing the complex tasks and processes occurring around us.

Unfortunately, these fascinating ideas are dulled by fairly repetitive writing. The concepts in this book are clearly valuable, and most people would find something new and exciting here. But as I'm sure the author would agree, the packaging of ideas can often be as important as the ideas themselves.

■■■■■

TOBIAS JOLLY is a statistician with an MSc in biochemistry

Rainbow Dust

Three Centuries Of Delight In British Butterflies

Peter Marren

Bloomsbury

From the voracious naturalists who once hunted and pinned vast butterfly collections to today's army of citizen scientists mobilised in the name of conservation, our changing relationship with butterflies tells us much about the way science has evolved. Peter Marren's book is a celebration of the role that butterflies play in our imagination and cultural lives, examining our enduring fascination for a group of invertebrates that has inspired artists and writers. While this is not a book on the hard science of butterflies, it does include intriguing discoveries and theories.

A captivating chapter on female butterfly enthusiasts explains how their scientific aspirations were often restricted to the nurturing of butterflies; another looks at the eccentricities of both common and scientific naming of species. We have had butterfly extinctions in Britain, unlike mainland Europe, and the book warns that species like the high brown fritillary or the Duke of Burgundy could be next without concerted action. But there is hope, as Marren explains, through our growing knowledge of butterfly ecology.

■■■■■

MATT SWAINE is a keen naturalist and the editor of BBC Wildlife magazine

Mindware

Tools For Smart Thinking

Eugenia Cheng

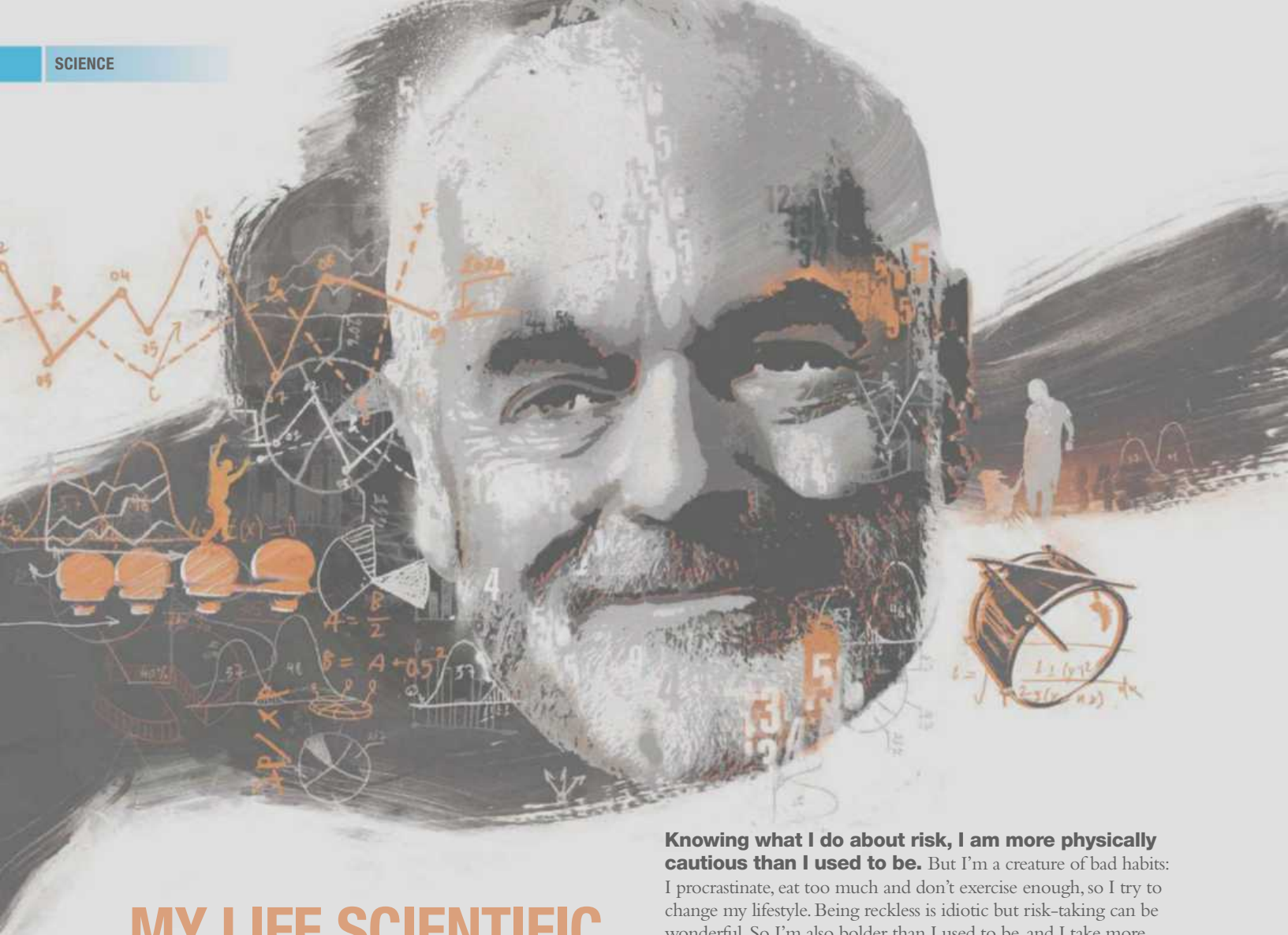
Allen Lane

Richard Nisbett's book, Mindware, is hard to review. From the cover blurb's overall tone, it's ostensibly a book about how the ways we think about things are often inefficient or inaccurate. Mindware sets out to show you how to avoid this flawed thinking and improve your rationalising and deduction skills. Technically, it could turn anybody into a real-life Sherlock Holmes.

However, there is just so much here. 'How people think' is a vast subject area, and Nisbett draws on so many disciplines (psychology, sociology, economics, philosophy and more), all of which are treated as equal (rightly or wrongly). This makes it very difficult to follow a coherent narrative or point. Nisbett is talented writer, although he can be rather self-aggrandising. What he's written is part textbook, part pop science, part personal musing, part self-help book, and probably more. It's great if you're into all that stuff, but it is tricky to keep track of what's being said and why.

■■■■■

DEAN BURNETT is a neuroscientist and comedian. He lectures at Cardiff University



MY LIFE SCIENTIFIC

DAVID SPIEGELHALTER

The UK's leading statistician tells Helen Pilcher why he's not very good at maths

I don't do maths. I'm not a good mathematician. But I do like using maths to handle numbers and data. I enjoy bringing order to chaos, looking for the signal in the noise, taking messy data and then extracting the structure from it. That's statistics, and it is fascinating because it provides a link between abstract mathematical thought and real world problems. Statistical modelling is used in everything from predicting football results to working out which drugs work – I've worked on both of these.

My biggest achievements include having over 70,000 citations on Google Scholar, which puts me in the top 10 in the world for statistics. For an academic, having piles of past publications is like a musician having an extensive back catalogue that they can live off.

But I'm also especially proud of my performance in an episode of *Winter Wipeout*. I was hopeless at the big red balls; in fact, I was hopeless at everything, to tell the truth. But I had studied the stats beforehand and so had trained to just keep moving for three minutes, and I ended up coming seventh.

Knowing what I do about risk, I am more physically cautious than I used to be. But I'm a creature of bad habits: I procrastinate, eat too much and don't exercise enough, so I try to change my lifestyle. Being reckless is idiotic but risk-taking can be wonderful. So I'm also bolder than I used to be, and I take more reputational risks. My latest book, *Sex By Numbers*, is a risk.

When I get the time, I play the surdo drum in a carnival band. It's the big thump-thump-thump thing that you hit with beaters. It's so loud that if you play it indoors it's a complete misery. In my downtime, I also like to go walking. I have a messy cocker spaniel called Daisy who comes with me.

People tell me statistics and probability are unintuitive and difficult. I've been working in the field for 40 years now and I've finally concluded that they're right. That's why it's important to explain it well. I was involved in public enquiries into children's heart surgery at Bristol Royal Infirmary and the murders by Harold Shipman. My main work now is translating risk into a form that people can understand, and it's great to have found something valuable to do.

I can't help feeling I have a strong case of Imposter Syndrome. I'm very lucky as I've found my niche – statistics. But on the outside, I think people have an over-inflated view of my abilities; on the inside, I feel there's a lot of winging it going on! That said, I've only got a few years to go before I retire, so I might just get away with it without being found out. ■

HELEN PILCHER is a science writer and comedian. She tweets from @Helenpilcher1

ILLUSTRATION: DANNY ALLISON

Time Out

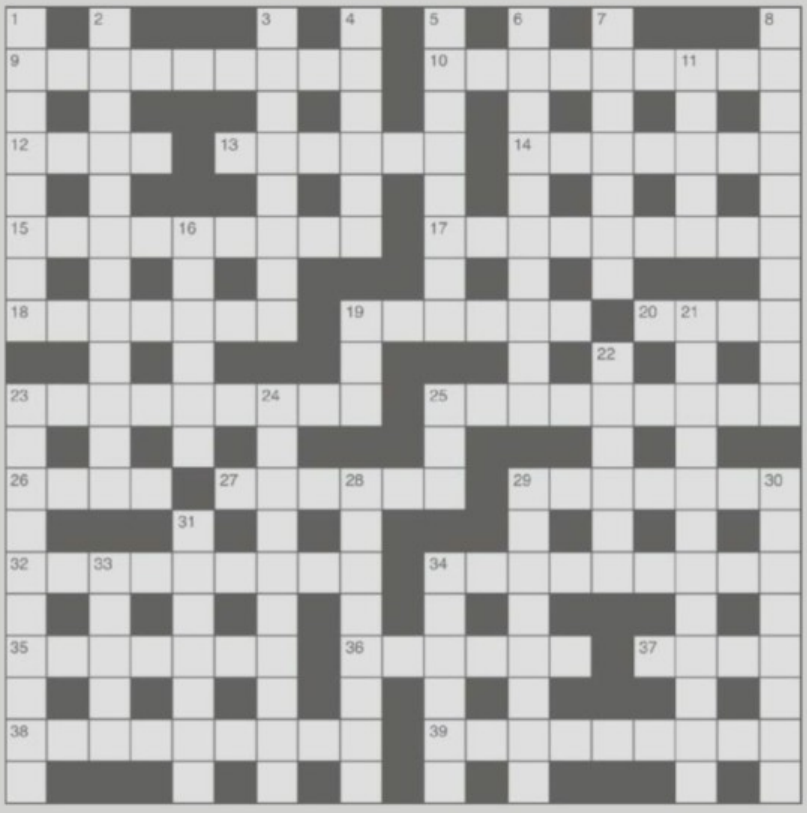
Crossword No.182

ACROSS

9 Tot's crib shook with energy of childbirth (9)
10 Respond with use of cane, meeting resistance (9)
12 European copper has right colour (4)
13 I like an ice cream to be symbolic (6)
14 I can't work with no radioisotope (7)
15 Raise plot using clay deposit (9)
17 Soldier in suitable American machine (9)
18 Hail old information – it leaves one cold (7)
19 Mr Henry pursues British fish (6)
20 The brook goes round the river (4)
23 Greek character in unusual toenail and hair removal (9)
25 Worry about bumpkin finding eastern squirrel (9)
26 Collapsed round part of church (4)
27 Register for a large drink (6)
29 A novice to object to part of Icelandic politics (7)
32 A termite's affecting temperature gauge (9)
34 Sprinkling huge pips round my head causes skin condition (9)
35 Bother to play old instrument (7)
36 Turn stomach over with the French accent (6)
37 Supporter of foul nature (4)
38 Large hoop displayed in oil print (9)
39 Article knocks identification of extinct reptile (9)

DOWN

1 In favour, since working for the law (8)
2 Scary sophist reinvented science (12)
3 Spinal treatment, being thrown into cart (8)
4 Cake gets caught on bracket (6)
5 Couple take in feline with feathered legs (8)
6 April wind swirling round a city (10)
7 Figure it has right height (7)
8 It's one solution – manage optical device (10)
11 Group transported tonne (5)
16 Only great recipe for a drink (6)
19 He's big in Scotland (3)
21 Yearning to get German girl a lens (7,5)
22 Draw small boat (6)
23 Delight in seeing some larks (10)
24 Inconsistent as a number (10
25 Copper gets point of signal (3)
28 Carriage uncovered with painful sound (8)
29 Affair gets republican journalist toughened (8)
30 Aged soul performed for composer (8)
31 Vespucci's first inspiration for country's name (7)
33 Scandinavian food (5)
34 Dish has a taste (6)



SOLUTION TO CROSSWORD 179

The Last Word

Maths can explain why 'silly season' formulas are complete nonsense

Forget barbecues and storms: nothing proclaims summer quite as reliably as 'silly season' stories. And they don't come much sillier than those proclaiming that 'Scientists have found the formula for the perfect…', well, you name it. Cheese on toast, relationships, handshakes – the list grows longer every year.

Everyone with an IQ exceeding their shoe size knows these stories are twaddle dreamed up by PR outfits. Sometimes they're put together with help from real scientists who really should know better. Some years back, I was offered a tidy sum of money to devise a 'formula' for the perfect loo brush or something. As it was clearly going to end up as the formula for appearing perfectly ridiculous, I declined.

I've since discovered that silly formulas aren't the preserve of desperate PR people. Over 150 years ago, the brilliant Victorian polymath Francis Galton devised what he regarded as the scientific formula for the perfect cup of tea. Here it is: (C+n)t = C+ne, where C is the volume of tea, n the number of ounces of tea used, t the temperature of the teapot and e the difference between the temperature of the water and the teapot.

I find it hard to believe Galton brewed this stuff up, as one glance shows it must be nonsense. That's because it breaks a law even more fundamental than the laws of physics: dimensional homogeneity.

"Everyone with an IQ exceeding their shoe size knows these stories are twaddle dreamed up by PR outfits"

Despite the name, the idea is very simple. Every physical quantity – area, velocity, force and the rest – is expressed in units known technically as dimensions, such as length, time and mass. They're the building blocks from which everything can be constructed.

For example, we measure area in units like square metres or square kilometres, so area is said to have 'dimensions' of length squared (L2). Similarly, because velocity is measured in metres per second, kilometres per hour and so on, it is said to have dimensions of length divided by time (L/T).

This leads to what one could call the Law of Laws: every valid formula must be dimensionally homogenous, having the same dimensions all the way through. Take Einstein's famous formula relating energy and mass, E=mc2. On the left, we have energy. This has dimensions of mass x length2 divided by time2, or Mx(L/T)2. Checking Einstein's formula we find its right-hand side is mass x the speed of light2, which also has dimensions of Mx(L/T)2. So Einstein's formula passes the dimensions test.

In contrast, Galton's 'law' fails. It's a ragbag of volumes, temperatures and pure numbers that don't even have dimensions. Most of those silly 'formulas for the perfect X' also fail the test. But the Law of Laws has a more positive side, by giving insights into what's important in a physics problem even when we're not entirely sure what to include. Simply demanding that both sides of a formula have the same dimensions can reveal that some apparently crucial factor is actually irrelevant, while others are more important than we might think.

For example, using such 'dimensional analysis' to find a formula for how far a bullet will travel reveals that the bullet's mass is irrelevant while its launch velocity is very important: doubling it quadruples the bullet's range. Theorists routinely use dimensional analysis for help in everything from aerodynamics to the quest for the ultimate Theory of Everything. And a quick check of the dimensions of those PR formulas will reveal that they're usually based on the Theory of Nothing. ■

ROBERT MATTHEWS is Visiting Reader in Science at Aston University, Birmingham

ILLUSTRATOR: DEM ILLUSTRATION

In this issue

Kelley Ferro eats her way through the amazing food of Fez

From art to culture, we hop from city to grasslands to discover beautiful landscapes and unusual art spaces

Make your way through honking traffic and feast on pho and banh mi in Vietnam's largest metropolis

Discover addictive aromas and indulge in all things sweet and savoury

The fashion capital of Japan beckons with its vivid eccentricity

GET YOUR COPY NOW!

Available at all major bookstores, petrol stations and newsstands, or subscribe online at www.e-shopping.sg

Win!
A One-Night Stay in a Deluxe Seaview Room at Batam View Beach Resort*

Win!
A Two-Nights' Stay at Aureum Palace Hotel & Resort Bagan, Myanmar*

A Publication of Regent Media


THE
HUNT
nothing is certain
© Grégoire Bouguereau
BBC earth
PREMIERES 2 NOVEMBER
MONDAYS AT 8.05PM (SG/HK)
BBC Earth is available in Hong Kong, Indonesia, Malaysia, Mongolia, Singapore, South Korea, Taiwan, Thailand and Vietnam.
Please call your cable operator for more details or check out our website.
www.bbcasia.com
/BBCEarth
@BBCEarthAsia